Visualization Tools for Visual Impact Assessments:
A study of immersive technologies

by

Anthony J. DePriest

A REPORT

submitted in partial fulfillment of the requirements for the degree

MASTER OF LANDSCAPE ARCHITECTURE

Department of Landscape Architecture/Regional & Community Planning
College of Architecture, Planning and Design

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2018

Approved by:

Major Professor
Dr. Tim Keane

Abstract:

Visual Resource Management practices are relatively new, dating back to the late 1960's and early 1970's (Litton, 1984; USDA Forest Service, 2010). At the conception of visual resource management practices, computers were not prominent in everyday life. As computing tools advanced along with easier access to technology, a perceived surge of research emerged within the VRM field in the 1990's. Since that time, it appears that few landscape architects have continued to research how modern technological advancements, specifically the recent expansion of virtual reality, could be used in predicting the visual impacts of proposed development. This report aims to compare virtual environments to existing methods for assessing the visual impacts of development in the Texas prairie ecoregion. New reliable tools at the hands of experts could lead to more accurate and more understood consequences of development on the visual landscape.

Following precedents set forth in similar research studies, participants will view photographic and rendered images of scenes before and after development projected through a digital display. Potential development will be analyzed through a comparison analysis in which multiple visualization methods (Google Earth and photo sphere images) are compared to industry standards of two-dimensional images and renderings. The comparison analysis will survey experts and ask them to rate certain views before and after development through multiple visualization methods.

Results from the study show a high similarity in perceived impacts between 2D images and Google Earth assessments. However, photo sphere images were rated consistently lower than their counterparts. Image resolution and detail could have led to the lower ratings in photo sphere images. Overall, participants felt that immersive visualization media will soon replace the use of 2D images for conducting visual impact assessments.

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Visual Resource Management practices are relatively new, dating back to the late 1960's and early 1970's (Litton, 1984; USDA Forest Service, 2010). At the conception of visual resource management practices, computers were not prominent in everyday life. As computing tools advanced along with easier access to technology, a perceived surge of research emerged within the VRM field in the 1990's. Since that time, it appears that few landscape architects have continued to research how modern technological advancements, specifically the recent expansion of virtual reality, could be used in predicting the visual impacts of proposed development. This report aims to compare virtual environments to existing methods for assessing the visual impacts of development in the Texas prairie ecoregion. New reliable tools at the hands of experts could lead to more accurate and more understood consequences of development on the visual landscape.

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Results from the study show a high similarity in perceived impacts between 2D images and Google Earth assessments. However, photo sphere images were rated consistently lower than their counterparts. Image resolution and detail could have led to the lower ratings in photo sphere images. Overall, participants felt that immersive visualization media will soon replace the use of 2D images for conducting visual impact assessments.

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List of Abbreviations

2D: Two-Dimensional
3D: Three-Dimensional
ANOVA: Analysis of Variance
BLM: Bureau of Land Management
FHWA: Federal Highway Administration
LCA: Landscape Character Assessment
NEPA: National Environmental Policy Act
NPS: National Park Service
SMS: Scenery Management System
SNH: Scottish Natural Heritage
USDA: United States Department of Agriculture
USFS: United States Forest Service
VIA: Visual Impact Assessment
VIA-HP: Visual Impact Assessment for Highway Projects
VMS: Visual Management System
VR: Virtual Reality
VRI: Visual Resource Inventory
VRM: Visual Resource Management

List of Terms

2D Image A photograph, hand, or computer (or some combination), drawn image that imitates a person or thing presented on a flat surface

3D Model A computer generated representation of an object that can be viewed in three dimensions

Augmented Reality Digital image superimposed onto a users live view through a device providing a composite view

Google Earth Model A computer program that allows users to view the world in three dimensions

Immersive Environments Technology that provides users with the perception of reality

Photo Sphere Image An immersive image that displays 360 degrees from a single point, allowing the viewer to look around.

Virtual Reality Computer generated environment displayed through a headset in which the user can interact with objects in a simulation, providing a lifelike experience

Visual Impact Assessment A study of the perceived visual changes on the landscape

Visual Resources The collective and generally accepted aesthetic appreciation of the visual landscape

1 Introduction

Figure 1.1: Cover Image

Introduction

Giving Context

The establishment of the National Environmental Policy Act of 1969 (NEPA) states that it is responsibility of the federal government to "assure for all Americans safe, healthful, productive, and aesthetically and culturally pleasing surroundings" (National Environmental Policy Act, Sec 101 [42 USC § 4331], 1969). In order to assure 'aesthetically pleasing surroundings', federal agencies developed methods to protect the visual resource that is the land. Agencies such as the Bureau of Land Management, the U.S. Forest Service, and the Federal Highway Administration created systems to analyze and rate visual changes to landscapes under their management. As the lands that they manage differ, so do the processes that they use to analyze visual changes. The methods developed became known as visual impact assessments.

Visual impact assessments play major roles in preserving the scenic value of landscapes. The Bureau of Land Management and the U.S. Forest Service allow companies to lease land for a period of time to extract certain resources such as ores and timber. Particular economic values are associated with the resource extraction, however there is an associated social value attributed to the aesthetics of landscapes.

Dilemma

As most visual impact assessment (VIA) practices require on-site observations, a combination of appropriate natural, climatic, and anthropocentric factors must be had in order to achieve the most appropriate results (Meyer and Sullivan, 2015). Most VIA practices strongly suggest that the assessment occurs during leaf-on conditions and in weather typical for the area (for visibility purposes), and for public lands, during the peak visitation season, all within a desired timeframe set by the client and developer. To be able to get enough assessors out to the often-remote sites and in the right conditions can be tricky and sometimes disappointing if the conditions do not remain as planned. Thus, being able to conduct an impact assessment remotely can be advantageous as time and resources allocated to send personnel to the site, could be spent elsewhere.

As natural, human, and climatic conditions can prevent the ideal assessment scenario, professionals began using color photographs and image collages as a tool for visualizing landscape changes. This study aims to expand upon the use of photographs by testing Google Earth and photo sphere images as possible media for visual impact assessments (see figure 1.2).

Research Question

How appropriate are Google Earth and photo sphere images as visualization surrogates for 2D images when conducting a visual impact assessment?

Do Google Earth and photo sphere images produce similar visual impact assessment results compared to 2D images?

Methods

Following precedents set forth in similar research studies, participants will view photographic and rendered images of scenes before and after development projected through a digital display (Shafer and Richards, 1974; Shuttleworth, 1980; Kellomäki and Savolainen, 1984; Stamps, 1990; Oh, 1994; Bergen et al, 1995; Heft and Nasar, 2000; Stamps, 2010). Potential development will be analyzed through a comparison analysis in which multiple visualization methods (Google Earth and photo sphere images) are compared to industry standards of two-dimensional images and renderings. The comparison analysis will survey experts and ask them to rate certain views before and after development using multiple visualization methods.

Virtual environments have opened the opportunity to give the user a fully immersive experience. The virtual environments used in this study are built in two ways. The first being through Google Earth by importing 3D models of potential projects into a scene. The second method requires a site visit in which a photo sphere image is taken by the researcher, potential development is added to the image through the Adobe Photoshop program.

The survey used for the research was developed in part by the author, working closely with Mark Meyer and Melanie Peters of the National Park Service and Robert Sullivan of Argonne National Laboratory. To develop the survey used in this study, the author analyzed existing visual impact assessment methods and held daily critiques over one month in the development of the survey design.

Relevance to Landscape Architecture

Visual resources are any and everything that can be seen. This includes not only physical landscape elements, but also cultural, recreational, and historical components. Since the National Environmental Policy Act (NEPA) mandate in 1969, landscape architects have often been entrusted with preserving the scenic landscape. Landscape architects have traditionally led visual impact assessments due to their education and training in understanding the visual and spatial components of the landscape. New technology and visualization methods have given landscape architects another tool that could be used to effectively assess visual impacts, and virtual environments like Google Earth and photo sphere images could play a major role in the preservation of scenic views.

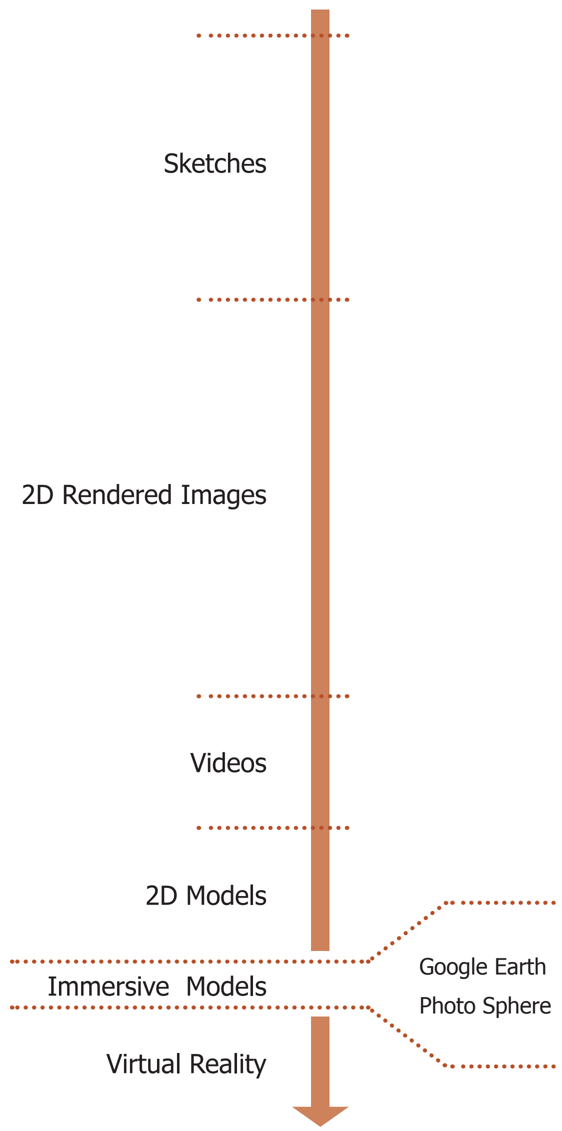


Figure 1.2: Research Focus

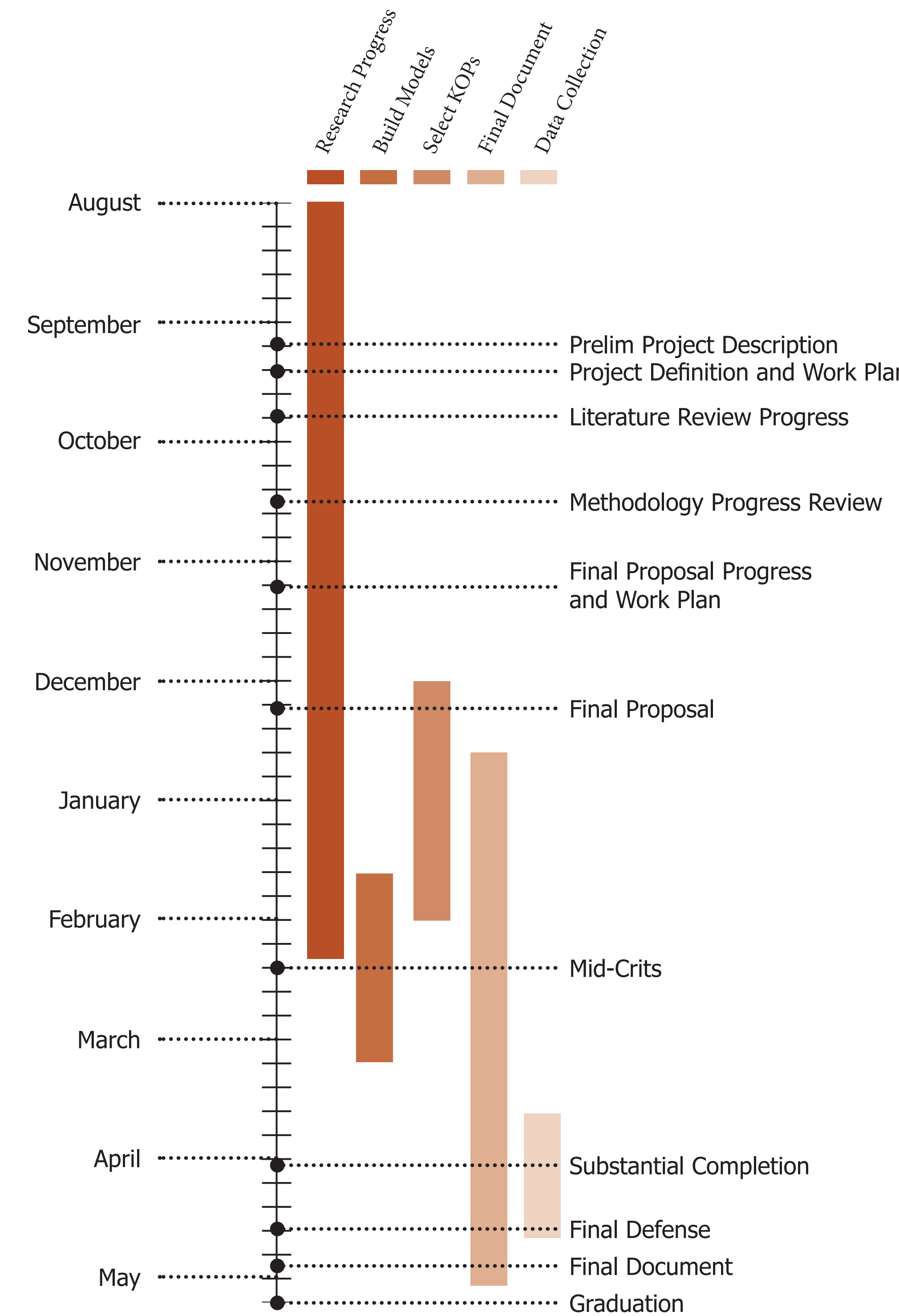


Figure 1.3: Work Plan

2 Literature Review

Literature Review

Existing Visual Resource Management practices and Impact Assessments

A visual impact assessment (VIA) is a tool used by numerous government agencies and private entities as a means to record and analyze the potential impacts that a new development will have on the visual landscape (Zube et al., 1982). Federal mandates in the late 1960's and early 1970's have stated the government's role in "ensur[ing] for all Americans… aesthetically and culturally pleasing surroundings" (National Environmental Policy Act (NEPA), Sec 101 [42 USC § 4331], 1969). Government agencies such as the Federal Highway Administration, the Forest Service, and the Bureau of Land management responded by including landscape aesthetic assessments as a standard exercise in environmental impact assessments. (Churchward et al., 2013). A perceived influx of research emerged shortly following the federal mandates, with another wave of research emerging in the 1990's coinciding with advancements in computer technology (Litton, 1968; Litton, 1974; Shafer and Richards, 1974; Stamps, 1990; Oh, 1994; Bergen et al, 1995; Heft and Nasar, 2000; Stamps, 2010). This section examines the collective body of knowledge of visual resource management (VRM) and visual impact assessment (VIA) practices (see figure 2.2).

In simplistic terms, visual resources are any and everything that can be seen. This includes not only the elements that make up the physical landscape (topographic elements, water features, vegetation, etc.), but cultural (landscapes with human significance), recreational (sports field, open fields, etc.), and historical landscapes (historic battlegrounds, memorials, etc.).

For this research, five existing visual resource management practices were reviewed to gain a better knowledge of their methods and to understand how and what tools are used in their assessment. The five systems reviewed were:

- The Bureau of Land Management | Contrast Rating System (BLM)
- United States Forest Service | Scenery Management System (USFS | SMS)
- Federal Highway Administration | VIA for Highway Projects (FHWA | VIAHP)
- National Park Service | Visual Resource Inventory (NPS | VRI)
- Scottish Natural Heritage | Landscape Character Assessment (SNH | LCA)

The five aforementioned methods were chosen because of their wide-spread use and accompanying documentation and research.

Although using different data collection processes, the five methods reviewed measure similar factors that are aggregated in measuring the predicted visual impacts of development. The BLM's contrast rating system analyzes forms, lines, colors, and textures in potential development that can contrast the surrounding landscape. Understanding how potential development contrasts the landscape has been studied by Robert Litton (1984) and is shown to be highly correlated to landscape representation and perception. This research utilizes the contrast of form, line, color, and texture between the existing landscape and proposed development, however, these factors do not fully encompass all variables that can affect perceived visual impact (Bureau of Land Management, a., 1986)

Similar to the BLM, the Federal Highway Administration analyzes form, line, color, and texture. The FHWA expands upon form, line, color, and texture to assess the proposed projects visual dominance, scale, diversity, and continuity within the landscape. In the FHWA VIA-HP the combined eight factors listed are organized in a category titled 'visual character' (U.S. Department of Transportation Federal Highway Administration, 2015). The National Park Service measures similar variables in view extent (dominance and scale) and inconsistent elements (diversity and continuity). Both agencies acknowledge the immediate contextual landscape and how the proposal will 'fit' into the view, as the FHWA and the NPS have to make assessments in both natural and highly developed areas. This study adapts the NPS's 'view extent' and the FHWA's 'visual character' to assess the visibility of proposed projects.

Visual and landscape character elements are commonly assessed variables in VIAs. Landscape character is defined by the SNH as "the distinct and recognizable pattern of elements that occurs consistently in a specific type of landscape". However, the process of making assessments in this study, landscape character is summarized as the visual language between a proposed project and its contextual landscape. The Forest Service, the Federal Highway Administration, and the Scottish Natural Heritage all assess the 'character' of the surrounding landscape as strong predictors of visual impacts (Swanwick, 2002; USDA Forest Service, 2010). Thus, understanding how a development fits into its environment is vital .

Tools

Each VIA method assessed utilizes similar tools, although the process of using such tools differs. All use a survey standard to their agency in assessing each proposed development but how the data is collected varies agency to agency. The three primary data collection methods either rely on expert testimony, public opinion, and in the ideal situation, both. The BLM, SNH, and the FHWA all rely on expert analysis when conducting a visual impact assessment while the NPS relies heavily on local park personnel, who for the most part, are not trained in landscape visuals. Public Participation is allowed for in the U.S. Forest Service's SMS, however, is considered pragmatic and tedious and often left out of studies (Churchward, 2013). Research has shown that experts view landscapes differently than the public, and since the reviewed methodologies are all public entities, involving the public in part of the process should be standard practice (Kellomäki and Savolainen, 1984). Churchward (2013) also argues that expert analysis will not always represent the opinions of the public, however, limitations prevented the use of the public in this study.

To aid in predicting visual impacts, assessors have utilized a plethora of visualization tools. The first established VIA practices in the early 1970's used black and white sketches, color drawn hand renderings, and black and white photographs as tools to help foresee potential visual changes. As technology advanced, research tested color photographs, photomontages, 3D computer models of varying detail, and video. The public agencies reviewed have typically relied on 2D photomontages and detailed descriptions provided by the developer, primarily due to resource constraints and untested methods. Private industry has begun utilizing very recent technology of augmented reality, virtual reality, and drones to better understand visual impacts (Jackson and Pfaff, 2017).

Visualizing VIAs

Most research about landscape aesthetics preference and visual impact assessments use a comparison analysis to rate viewer responses to existing and proposed landscape changes. Starting in the 1980's, computer generated landscape models and photographs have been used as the primary source of estimating the perceived visual alterations that development has on the landscape. Extensive research has been conducted to determine the validity and reliability of photographs and renderings as a means to accurately convey changes (Daniel & Meitner, 2001; Scott & Canter, 1997; Stamps III, 1990; Hull and Stewart, 1992; Hetherington *et al.,* 1993). Their research predominantly points to the high degree of accuracy in which photographs replicate landscape aesthetics. Photographs being able to replicate landscapes sets up the basis that people can perceive landscapes by means other than being on site.

Validity of Visualizations

Landscape aesthetic judgments have used photographs in an attempt to accurately represent environments and perceived visual alterations. A multitude of research studies have demonstrated a high correlation between a visualized landscape and on-site experiences. (Shafer and Richards, 1974; Shuttleworth, 1980; Kellomäki and Savolainen, 1984; Stamps, 1990; Oh, 1994; Bergen et al, 1995; Heft and Nasar, 2000; Stamps, 2010). Provided below is an overview and analysis of the existing literature. Completed in part by the USDA Forest Service, Shafer and Richards' (1974) study aimed at comparing observer reactions to viewed landscapes and photographs of the same scenes. Three groups of around 30 participants each, analyzed eight different scenes in and around Syracuse, New York that depict a variety of landscape types from waterfalls to junkyards. Group A was tasked with analyzing on-site observations, group B evaluated color slides while group C assessed color photographs. To collect data, the researchers listed 27 adjective descriptors and their antonyms (e.g. Open vs enclosed, public vs private, etc.) with all 27 pairs being rated on a seven point rating scale. The semantic differential descriptors, found in several studies (Shafer and Richards, 1974; Kellomäki and Savolainen, 1984; Oh, 1994) were given to gain an understanding of user opinions. Shafer and Richards concluded that overall, photographs and color slides receive similar viewer responses to on-site observations, equating the representation to reality (Shafer and Richards, 1974). By finding similar responses, this study implies that an observer does not have to be on-site in order to understand and interpret a landscape.

Kellomäki and Savolainen's investigation (1984) concentrated on in-the-field and off-site tests over the scenic beauty of forest landscapes in Finland. Similar to Shafer and Richards study, responses from an on-site questionnaire were used to compare viewer reactions of photographs of the same landscapes. A list of antonymous adjectives were given to participants to use as evaluative criteria when assessing each forest view. Two groups of participants were used in this study; forestry students and "city dwellers". The results of the study showed two different themes. The first being that forestry students and "city dwellers" had different perceptions of the landscape. The second results of this study showed that correlation coefficients between photographs and on-site observations ranged from 0.830 to 0.957, indicating a high positive to very high positive correlation (1 being perfectly correlated and 0 showing no correlation). The high correlation between on-site and off-site further suggests that off-site assessments can be as reliable as on-site observations (Kellomäki and Savolainen, 1984; Mukaka, 2012).

Digitizing Displays

Hetherington et al. (1993) as well as Heft and Nasar (2000) looked to expand upon the use of photographs in landscape aesthetic judgements and evaluate the use of dynamic displays, such as videos, in conducting comparative assessments of on-site evaluations to digital simulations (Hetherington et al., 1993; Heft and Nasar, 2000). Perceptions surrounding the use of dynamic displays would provide the assessor with new perspectives, more context, and a more experiential realm in which the viewer could imagine themselves. Hetherington et al. observed three different visualization methods; video with sound, video without sound, and still photographs (Hetherington et al., 1993). Videos allow evaluators to move throughout the space, while applying an underlying function to the user, whether that be driving on a road, walking or hiking, riding a bike, etc. Assigning function could lead to implied emotions or feelings, such as the feeling of exhaustion when hiking a trail (Hull and Stewart, 1992). Videos lend themselves to introduce other sensory experiences that would not be possible through the use of photographs. Such sensory experiences would primarily be the combination of sight and hearing.

Similar to Hetherington, Heft and Nasar (2000) compared video recorded from a vehicle travelling along rural roads to static images taken from the video. Although not stated, it can be assumed that audio was not included in their video due to the nature of the recording process. Interestingly, both studies found that the use of videos lowered viewer preference slightly. In Hetherington et al., video with sound had an average reliability rating of 0.90 compared to static images, video without sounds average reliability was 0.85, and static photographs had an average reliability of 0.93 (Hetherington et al., 1993). The reliability values show an overall high correlation between photographs and video. The similarities of the correlations implies that

video with sound could be used as a surrogate for still photographs. Heft and Nasar (2000) state that "preference ratings appear to be elevated for static displays relative to dynamic displays" and is demonstrated through their findings in which the correlation coefficient of static displays to landscape preference is .96 and dynamic display to view landscapes is .92 (Heft and Nasar, 2000, pg. 315).

Kyushik Oh (1994) found that two-dimensional digital models had highly correlated viewer responses to photographs. Oh studied different types of computer generated landscape models to observe how viewer responses changed from the computer models to still images. Oh analyzed four different landscape models; a wireframe model (existing of points and lines), a surface model (consisting of points, lines, planes, and colors/textures), combined surface model with photographic images, and image processing (editing scanned photographs to allow for realistic textures and colors). Using three different viewpoints, twelve models were created (the four model types at three viewpoints) that looked towards a new building on a university campus. To assess viewer preference, the participants (college students aged 18-46, average age of 22.5) were asked a series of descriptors and their antonyms (Bipolar semantic descriptors) of the view, appraisals of the view, with an open-ended comment section provided. Results of Oh's study found a high correlation between photographs and all the models with the exception of the wire frame. Image processing had the most similar viewer responses to photographs, closely followed by the surface model and the combined surface model (Oh, 1994). This research implies that computer generated three-dimensional models displayed in a two-dimensional format can accurately represent a landscape, as long as the models are built to a level of detail beyond wire frame models.

Computing technology has advanced significantly since the time of Oh's (1994) study. Modern computers allow for greater detail and larger models to be generated. It can be argued that Oh's findings hold true today because professionals employ similar computer modeling techniques, although displayed at a finer level of detail. As demonstrated by Daniel and Meitner (2001) and implied by Oh, more detail provided in a model or image is interpreted by viewers as being more lifelike (Daniel and Meitner, 2001; Oh, 1994). Viewers can gain a better understanding of the landscape through more realistic and accurate models and images. The correlation between 3D computer models and on-site observations indicates the ability of 3D models to act as a surrogate for going to the site.

A meta-analysis conducted by Stamps (2010), observed user responses to visual preference between three media: on-site observations, static images, and dynamic viewing methods. The meta-analysis investigated 33 research studies in which approximately 3,500 participants tested 451 scenes. Stamps suggests that, for landscape visualizations, static displays would work best for two reasons; time efficiency and cost efficiency (Stamps III, 2010). It can be argued that, when evaluating landscapes for visual change, dynamic displays such as virtual reality could be just as accurate as static displays and more time and cost efficient (Slater and Sanchez-Vive, 2016). Many of the public agencies require site visits for observations and data collection (Bureau of Land Management, b, 1986; Meyer and Sullivan, 2015). Public agencies manage millions of acres of land and a credible business model would show that having a central (off-site) location in which assessments were made would be more time and cost efficient than training hundreds of people across the United States, which is current practice. Training employees on-site would require travel expenses and time that could be used elsewhere. The researcher acknowledges that dynamic displays might not be the most appropriate method in every VIA (Stamps III, 2010).

Arguments Against Artificial Representations

Separating itself from most studies of photographic validity in visual impact assessments, Hull and Stewart observed individuals as a unit of analysis, rather than a collective group, arguing that individuals are "the experiential units responding to landscape stimuli" (Hull and Stewart, 1992, pg. 102). In this study, 90 participants volunteered to collect data while hiking along a trail in White River National Forest. In addition they noted two follow up assessments of photographs from the same points three months and nine months later. Along the route were 12 observation points in which the participants would rate views using a seven-point Likert scale. To assess each view, two questions were proposed. The first question asked, "How does the scenic beauty of the area depicted by this photo (or by this landscape for on-site observations) compare to the most beautiful view you can remember" and the second one rated a viewer's desire to see views similar to the selected observation point. Three and nine months later, participants were asked to indicate how they would rate their experience based solely on the photograph. (Hull and Stewart, 1992, pg. 104).

Results of Hull and Stewart's (1992) study reflected concerns of the validity of photographs in landscape representations (Hull and Stewart, 1992). The correlation between on-site and scenic beauty ratings and photo-based ratings found an average p factor of 0.60 with a median p of 0.68. Thirty-eight percent of individuals had correlation coefficients less than 0.60, rendering the finding slightly correlated, yet not significant enough to confirm findings one way or the other. Critique of this study lies in the nature of data collection. Participants gathered data whilst completing a strenuous hike or passively analyzing photographs (Hull and Stewart, 1992). Physical exhaustion can lead to conflicts of psychological and physical variables when assessing scenic beauty, but Daniel and Meitner (2001) argue that issues in the validity thought to be caused by psychophysical activities are negated by the significantly uncorrelated findings between on-site observations and photograph analysis in Hull and Stewarts study.

Similar to Hull and Stewart, a study conducted by Scott and Canter (1997) found validity concerns with the representation of photographs for landscape assessments. In their study, Scott and Canter had several groups' of 11-18 year olds participate from a local secondary school in North Yorkshire, England. The researchers held group discussions with the participants in which potential sites for photographs were suggested. Throughout this process, 20 photographs were taken by the researchers from locations based on three factors; the physical landscape elements within the view, the potential use of the space, and the associated cognition of the location. In their first observation, students were tasked with sorting the photographs into categories of their choosing. The second task required the students to engage sensory experiences of the pictured landscape. The participants were to sort the images based upon perceived feelings of sight, audio, scent, how they would feel, and their mood/emotion. The third tasked aimed at how the participants experience the sense of place, rather than solely observing the pictured landscape and its representation. The participants were asked to record the categorization process including the descriptive factors associated with each group made. Forty-one participants in the first task generated 98 different descriptors that the researchers categorized in seven different types (Scott and Canter, 1997). The researchers concluded that people understand and interpret photographic content differently than they conceptualize the 'place' in an image (Scott and Canter, 1997).

This study demonstrates that viewers can see similar attributes, but that they conceptualize experience of places differently. In relation to landscape aesthetics and scenic beauty assessments, the research conducted by Scott and Canter imply that a judgment in landscape aesthetics could have larger implications than previously thought, since most modern assessments are conducted by a single user or small groups that do not fully represent a larger population. To have a more well rounded assessment, Scott and Cantor (1997) suggest that having a larger panel of assessors will lead to more representative results. This opens the opportunity to explore virtual reality, in which immersive experiences can be distributed to masses without them needing access to the site. A more immersive experience could aid in the conceptualization process by creating a similar experience across assessors (Slater and Sanchez-Vive, 2016).

Virtual Environments

Virtual environments can be described as any digitally rendered setting. This research tests two different virtual environments; Google Earth and photo sphere images. These virtual environments can be used as cognitive tools in which "a user can interact with 3D models and agents in a virtual environment" (Bruno et al., 2010). Virtual Reality (VR) and virtual environments have been imagined since the mid-1960s, although not in the form that we know today (Sutherland, 1965). With the advancement of computer technologies today in tandem with more affordable systems, the availability and potential for immersive virtual environments could become a reality.

Virtual environments can provide users with a fully immersive experience in which multiple senses can be stimulated. Because of its immersive capabilities, a large number of studies have used virtual reality in particular within broad research topics ranging from social and physical experiences to education and training to traveling and to health and well-being (Jack, 2001; Spicer, 2003; Saposnik et al., 2010; Slater and Sanchez-Vives, 2016).

Virtual Reality

With respect to landscape planning, Orland et al. (2001), argues that virtual reality "will increasingly be looked on to replace existing land management procedures" (Orland et al., 2001, 147). Their study analyzes existing literature and ideals of virtual reality and its future use in landscape planning. Similar to Oh (1994), the researchers state the virtual reality models must reach a threshold of perceived realism in order for users to be able to represent landscapes accurately,

although they do not show evidence for such claim. However, Orland et al. (2001) expresses skepticisms of VR because flaws in the model and in the visualization, can be altered to show what a user group would prefer, rather than an unbiased view. The researchers conclude by stating that more research needs to be conducted to determine VR development and validity before using it to make land planning decisions.

For the purpose of this research, Google Earth is compared to traditional 2D images. Google Earth is a free 3D visualization program that can be used across multiple hardware components, including VR specific head units such as the Oculus Rift and HTC VIVE, but can also be simply used with any modern smart phone. Head units exist that allow a smart phone to turn into a virtual reality system, but without the headset, the phone will work similar to a photo sphere image. In Google Earth, users have the capabilities to travel to different locals, walk and fly to experience places in a unique and immersive way. Like Google Earth, the program has the capabilities to insert preconfigured, as well as custom, 3D models into user defined spaces (Google, 2017).

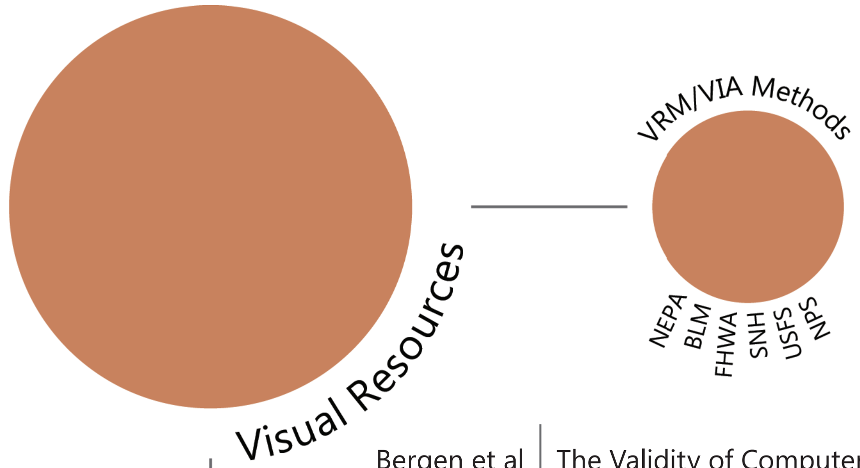
Photo Sphere Images

Similar to Google Earth, photo sphere images allow the viewer to experience 3 dimensional spaces but to a different level of detail. Google Earth uses satellite imagery that can have difficulties rendering trees and complex landscapes. A photo sphere images can be taken with any modern smart phone or photo sphere specific camera at any location, and detail is only limited to the lens capabilities. However, photosphere images are grounded to a specific point in space, where the photo was taken, whilst Google Earth allows users to fly through space. 3D photosphere images can be edited through image processing software such as Adobe Photoshop.

Summary

Since the mandate of visual impact assessments in 1969, varying methods and tools have been used to assess the impacts of proposed developments on the visual landscape. This literature review observed exiting visual resource management and visual impact assessment methods and their associated tools. Common themes emerged from the methods such as landscape and visual character, landscape elements like form/line/color/texture, inconsistent elements, and view extent. These factors helped to inform the survey that is used for assessing new visualization methods for impact assessments. This literature review also documented past visualization tools used for predicting visual impacts from black and white sketches to advanced computer modeling techniques. The literature demonstrated a gap in research that relates to new technologies, specifically virtual reality systems (Google Earth) and photo sphere images.

Gaining more knowledge of existing practices helped to inform the survey design used in this study, along with assistance from trained professionals.



Bergen et al	The Validity of Computer-Generated Graphic Images of Forest Landscapes
BLM	VRM Manuals
Bruno et al	From 3D Reconstruction to Virtual Reality: A complete Methodology for Digital Archaeological Exhibition
Daniel and Meitner	Representational Validity of Landscape Visualizations: The Effect of Graphical Realism on Perceived Scenic Beauty of Forest Vistas
FHWA	NCHRP Report, Guidelines for Visual Impacts
Heft and Nasar	Evaluating Environmental Scenes using Dynamic Versus Static Displays
Hetherington	Is Motion More Important than it Sounds? The Medium of Presentation in Environmental Perception Research
Hull and Stewart	Validity of Photo-Based Scenic Beauty Judgments
Jack	Virtual Reality: Enhance Stroke Rehabilitation
Kaplan	Aesthetics, Affects, and Cognition: Environmental Preference from an Evolutionary Perspective
Keane	The Role of Familiarity in Landscape Aesthetics: A Study of Tallgrass Prairie Landscapes
Kellomaki and Savolainen	The Scenic Value of Forest Landscapes as Assessed in the field and the Laboratory
NEPA	Guidelines
NPS	NPS VRI Scenic Quality
Oh	A Perceptual Evaluation of Computer Based Landscape Simulations

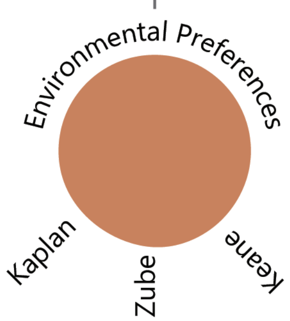
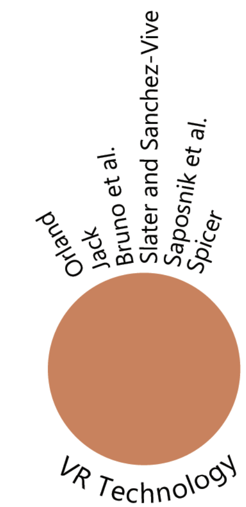
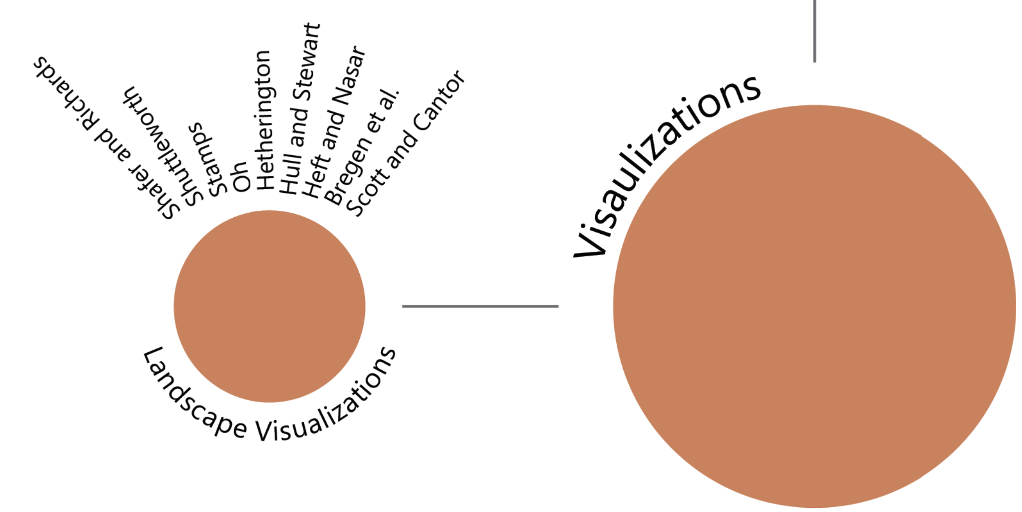


Figure 2.2: Map of Literature

Orland et al	Considering Virtual Worlds as Representations of Landscape Realities and as Tools for Landscape Planning
Saposnik et al.	Effectiveness of Virtual Reality Using Wii Gaming Technology in Stroke Rehabilitation: A Pilot Randomized Clinical Trial and Proof of Principle
Scott and Cantor	Picture of Place? A Multiple Sort Study of Landscape
Shafer and Richards	A Comparison of Viewer Reactions to Outdoor Scenes and Photographs of Those Scenes
Shuttleworth	The use of Photographs as an Environmental Perception medium in Landscape Studies
Slater and Sanchez-Vive	Enhancing Our Lives with Immersive Virtual Reality
SNH	Landscape Character Assessment
Spicer	Virtual Reality Surgery: Neurosurgery and the Contemporary Landscape
Stamps	Use of Photgraphs to Simulate Environments: A meta Analysis
	Use of Static and Dynamic Media to Simulate Environments: A Meta Analysis
Sutherland	The Ultimate Display
USFS	Landscape Aesthetics Handbook, Scenery Management
Zube	Landscape Perceptions: Research, Application and Theory





3 Methodology

Figure 3.1: Cover Image

Methodology

Research Questions

How appropriate are Google Earth and photo sphere images as visualization surrogates for 2D images when conducting a visual impact assessment?

Do Google Earth and photo sphere images produce similar visual impact assessment results compared to 2D images?

Method

The method used in this research stems from Rachel Kaplan's (1985) rating preference system. Kaplans rating preference system has been used in numerous landscape visual studies and has been described as a simple and accurate method to collect landscape visual data (Kellomäki and Savolainen, 1984; R. Kaplan, 1985; Oh, 1994). The participants of the study will view photographic and rendered images of scenes before and after development projected through a digital display (see figure 3.2). For this research, eight observation points are used. Three visualization methods are assessed at each observation point, leading to 24 assessments made. The three visualization methods used in this study are 2D images, Google Earth, and photo sphere images.

Goals

The goal of the methodology was to collect data that compares perceived visual impacts between two-dimensional images, photo sphere images, and Google Earth.

Participants/Target Audience

In the landscape planning industry, experts conduct visual impact assessments to anticipate and plan for visual changes in the landscape. This study utilized 23 professionals as participants. The expected audience of the research will be professionals in both the public and private sector.

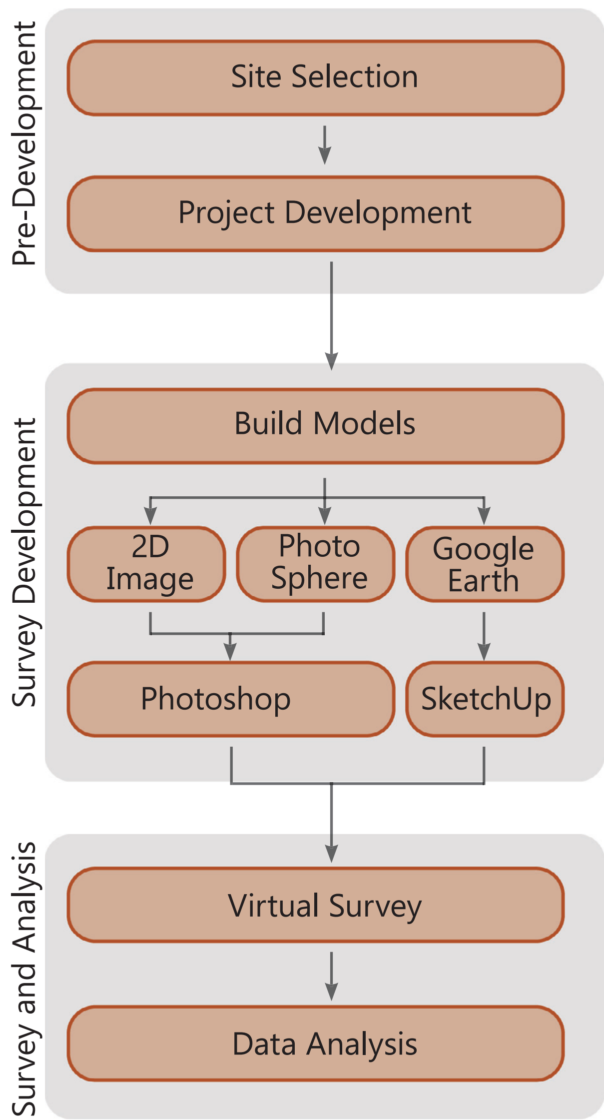


Figure 3.2: Methodology Diagram

Recruitment Process

A first round of potential participants were those who attended the professional Visual Resource Stewardship conference. The Visual Resource Stewardship Conference occurred November 7-9, 2017 at Argonne National Laboratory. Emails were sent out to attendees asking if they wished to participate. Further participants came from recommendations provided by previous participants.

Variables

Dependent Variable: Perceived Visual Impact
Independent Variable: Visualization Method (2D image, Google Earth, photo sphere image)

Approach

Step 1: Selecting Sites

The first step of this research was to find suitable observation points from which assessments were made. Observation points for the research were conducted in the grasslands and pastures around Waco, TX. Viewpoints were selected based upon visible land area and land cover type.

Landscape preference studies have found the combination of open-landscapes, and visible distance (landscapes with high visible land areas) are preferred over enclosed landscapes (Iverson, 1985; Clayton and Opotow, 2003). Land cover collected from the National Land Cover Database (2011) is used to accumulate viewpoints that overlook developed, natural, and cultural landscapes. A balance of developed, natural, and cultural land cover within views was desirable to accurately represent visible landscapes of the region (United States Geologic Survey, 2011).

At each observation point, a photograph and a photo sphere image were taken. In total, 8 observation points be collected for the research. The goal was to acquire varying types of views based upon the aforementioned factors of land cover type, visible land area, and viewpoint importance. By having a variety of view types, the results of the study gain credibility and validity within this ecoregion.

Step 2: Project Development

Hypothetical developments were generated and placed in the landscape in order to test the anticipated visual impacts. The development of the hypothetical projects were based on two factors; development type and its location in the landscape. Projects were be based on developments consistent to development found in the surrounding landscapes. Potential projects included were large scale wind farms, singular wind turbines, and oil pump jacks.

Step 3: Building Models

This study required three different visualization models to be built, one for each of the visualization method. The models are the 'after' images, in which the development is being assessed. For two-dimensional models, this process was rather simple. A photo montage was rendered in which the proposed developments were produced through Photoshop and scaled appropriately. Google Earth utilized existing three-dimensional models that can be placed into the landscape. A model was then placed into its desired location. To test the different visualization methods, the development models were not the same images used in the 2D images or in photo sphere images. Building models for photo sphere images utilized functions in the Adobe Premier and Adobe Photoshop programs, and similar to the Google Earth, a three-dimensional model was placed into the landscape.

Step 4: Virtual Survey

The survey used in this study was sent to the participants via email. As part of the online survey, participants must acknowledge and accept to participate in the study. The first page of the survey was used as an informed consent, giving the researcher the ability to use their survey data. Declining to participate resulted in the survey being terminated.

The next step in the online survey requested some personal information. The personal information section asked for the participants work experience, education/training, which sector they work in, and how active he/she is in the outdoors. No identifying information was collected within this section, and participants could decline to submit if they feel 'at risk' with any information.

Once the personal information section of the survey was complete, the participants began the assessment phase. In this section, eight observation points are displayed through three different visualization methods at each point. In total, 24 assessments were made. The order in which the observation points and visualization methods presented were randomized so participants did not see similar sites or image types one after the other. For every assessment made, before and after images of the potential development were presented side by side. This allowed the participant to go back and forth between before and after to easily visualize changes in the landscape.

To make the assessment, the participant rated the impacts within each view on six different elements. Each factor was rated on a one to five Likert scale with a 'one' having the least visual impact and a 'five' having the highest visual impact. Descriptors of how each element should be rated were given, to ensure a consistent approach across all participants. The first element rated was character type and how well the development matches the landscape character. The second rated element was view extent and how much the project encompasses the view. The third rated element, contrast, examined how much the project contrasted its surroundings in terms of forms, lines, colors, and textures. The fourth variable rated tested how the development added/subtracted focal points in the view. The fifth element surveyed how the development was similar to other development in the view (if any).

The survey (page 101, appendix B) was developed in part by Mark Meyer and Melanie Peters of the National Park Service, and Robert Sullivan from Argonne National Laboratory, and the author of this research through analyzing each of the major land managing government agencies visual impact assessment processes. The agencies analyzed includes the Bureau of Land Management, the United State Forest Service, the Federal Highway Administration, as well as the Scottish Natural Heritage.

Step 5: Data Analysis and Aggregation

Lastly, collected data was aggregated from the survey. For the comparison, the Kruskal-Wallia test, the one-way analysis of variance (ANOVA) test, and the Spearman correlation could all be used. The best statistical analysis type for this study was the one-way ANOVA test because it was able to analyze three or more categories within the independent variables.

In this study, the three categories of the independent variables (visualization methods) were 2D images, Google Earth, and photo sphere images. P values were calculated to determine the level of correlation between the differing visualization methods. For this research, a significance value of less than 0.05 indicated significant difference between variables. From the survey responses, the means of the five rated variables (change in landscape character, view extent, contrast, focal points, and inconsistent elements) were compared between the three visualization media. To compare means scores across the three media formats, a total mean value was calculated between the five rated elements. Mean values can range from 1 to 5. A mean values closer to 5 indicates a high level of visual impact while a mean value closer to 1 indicates a low visual impact.

As part of the survey, demographic data was collected and analyzed to see if trends occurred between ratings and age, gender, and experience. To identify trends, one-way analysis of variance was conducted again, with the Tukey Post Hoc analysis to identify where groups differed.

4 Results

Figure 4.1: Cover Image

Results

The purpose of this study was to test immersive visualization technologies potential in conducting visual impact assessments. Eight viewpoints were represented through three different visualization media in a survey that was sent to 75 researchers and professionals whom all have interest in visual resources. Through 23 responses, a one-way ANOVA analysis was used to compare the mean values of 2D images, photosphere images, and Google Earth. Once the analysis of variance was completed, the Tukey Post Hoc test was conducted to identify the variables in which significant differences occurred. Further analysis was conducted in which the five variables used in the assessments differ from each visualization media. The five rated variables in the assessments are the change in landscape character, view extent, contrast, focal points, and inconsistent elements. Demographic data of the assessors and their ratings was conducted to discover any possible trends.

The analysis of variance showed that on average, assessors rated photo sphere images lower than 2D images or Google Earth (Table 4.1). The means values in this test were determined by averaging out the five rated elements used in each assessment from all viewpoints and all participants. On average, participants rated 2D images (μ = 3.21) and Google Earth (μ = 3.20) consistently, yet Google Earth had a slightly higher standard deviation (1.42) compared to 2D images (1.26). However, photo sphere images were rated with a mean value of 2.73. The lower mean value associated with photo sphere images indicates that participants feel as if development will have less of a visual impact compared to 2D images of Google Earth. Figure 4.2 graphically represents the minimum and maximum average rating, along with the 95% confidence interval and the men values of each visualization method.

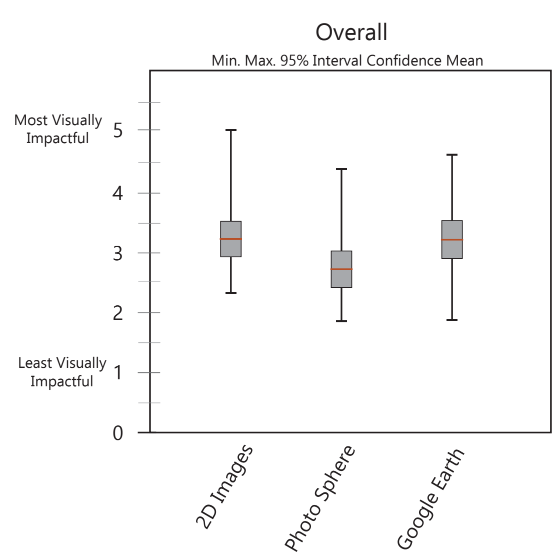


Figure 4.2: Overall Results

Overall Ratings

	N	Mean	Std. Deviation	Std. Error	95% Lower Bound	95% Upper Bound	Minimum	Maximum	Sig	*F*
2D Images	23	3.22	0.672	0.14	2.93	3.51	2.33	5		
Photo Sphere Images	23	2.73	0.384	0.143	2.43	3.02	1.78	4.4		
Google Earth	23	3.2	0.821	0.169	2.85	3.55	1.78	4.63		
Total	69	3.05	0.75	0.09	2.87	3.23	1.78	5	**0.041**	**3.357**

Table 4.1: Comparing Visualization Methods

Variables

The next step of the analysis was to analyze which rated variables in the survey (change in landscape character, view extent, contrast, focal points, and inconsistent elements) were causing photo sphere images to receive a lower average rating. Similar to comparing the results above, a one-way analysis of variance was conducted on the five variables, along with the Tukey Post Hoc test. To calculate the differences, one dataset was generated by aggregating the 23 participants rating of the variable from each viewpoint, totaling 184 data points.

Character Type

The first variable assessed was character type. Character type judges how the proposed development changes the overall identity of the viewed landscape. In table 4.2 it can be seen that the mean rating values between 2D images (μ = 3.00), photo sphere images (μ = 2.93) and Google Earth (μ = 3.22) differ slightly, yet no significant difference was reported (F = .455, p = 0.796). With photo sphere images being rated the lowest, as shown in figure 4.3, no significant differences were found meaning that based upon the change in landscape character, the three visualization methods would produce similar results.

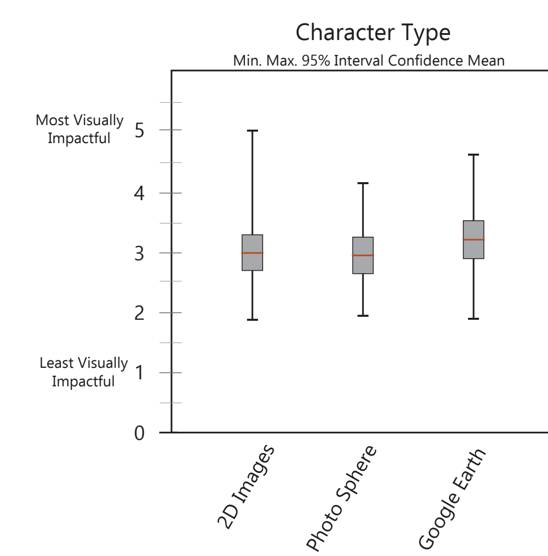


Figure 4.3: Character Type

Character Type

	N	Mean	Std. Deviation	Std. Error	95% Lower Bound	95% Upper Bound	Minimum	Maximum	Sig	*F*
2D Images	23	3	0.854	0.178	2.63	3.37	1.75	5		
Photo Sphere Images	23	2.93	0.698	0.146	2.63	3.23	1.88	4.25		
Google Earth	23	3.22	0.858	0.149	2.85	3.59	1.75	4.63		
Total	69	3.05	0.804	0.097	2.86	3.24	1.75	5	**0.796**	**0.455**

Table 4.2: Character Type

View Extent

	N	Mean	Std. Deviation	Std. Error	95% Lower Bound	95% Upper Bound	Minimum	Maximum	Sig	*F*
2D Images	23	3.15	0.775	0.162	2.71	3.78	1.75	5		
Photo Sphere Images	23	2.35	0.952	0.199	1.94	2.76	1.25	4.375		
Google Earth	23	2.98	1.06	0.221	2.53	3.44	1.25	5		
Total	69	2.83	0.986	0.119	2.59	3.06	1.25	5	**0.013**	**4.659**

Table 4.3: View Extent

View Extent

The second variable analyzed was view extent, in which the participants rated the overall visibility of the proposed project. One-way ANOVA shows significant differences (F = 4.659 p = 0.013) between the mean values of 2D images (μ = 3.15), photo sphere images (μ = 2.35), and Google Earth (μ = 2.98) (table 4.3). A Tukey Post Hoc test concluded that the photo sphere images differed significantly from 2D images and Google Earth, yet no significant difference occurs between 2D images and Google Earth (figure 4.4). This was the first variable in which photo sphere images were rated significantly lower than the other visualization media. The lower rating of the photo sphere images can be conceivably attributed to two different possibilities. The first possibility is that immersive technology like photo sphere images allows the viewer to experience a scene in 360°, while 2D images provide a focused view. The focused view of the 2D image emphasizes the proposed project, whilst the immersive image gives more insight to the larger context in which the proposal is located. The second possibility is that the fish eye camera lens and process used

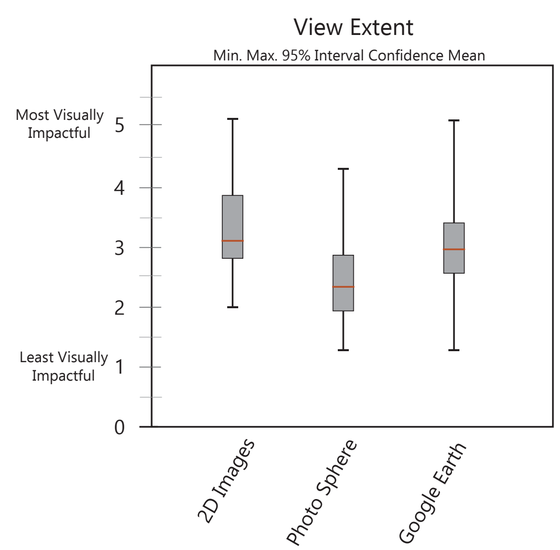


Figure 4.4: View Extent

images loses detail the farther elements are from the viewpoint, the more it blends in with its surroundings becoming less visible.

Contrast

Contrast, the third variable analyzed, assessed how the proposal contrasts the existing landscape in terms of form, line, color, and textures. The one-way ANOVA again shows in table 4.4 that photo sphere images (F = 4.063, p = 0.022) had a lower rating mean (μ = 2.64) when compared to 2D images (μ =

3.26) and Google Earth (μ = 3.28). Having very similar means, no significant differences were found between 2D images and Google Earth. However, the Tukey Post Hoc test determined that there is significant difference between photo sphere images and 2D images/Google Earth to a significance value of $p < 0.05$. The main hypothesis as to why photo sphere images received a lower rating is due to detail being lost in the images the further from the view point landscape elements are.

Contrast

	N	Mean	Std. Deviation	Std. Error	95% Lower Bound	95% Upper Bound	Minimum	Maximum	Sig	*F*
2D Images	23	3.26	0.77	0.161	2.922	3.59	2	5		
Photo Sphere Images	23	2.64	0.859	0.179	2.65	3	1.63	4.5		
Google Earth	23	3.28	0.96	0.2	2.86	3.69	1.38	4.625		
Total	69	3.06	0.905	0.109	2.84	3.27	1.38	5.00	**0.022**	**4.063**

Table 4.4: Contrast

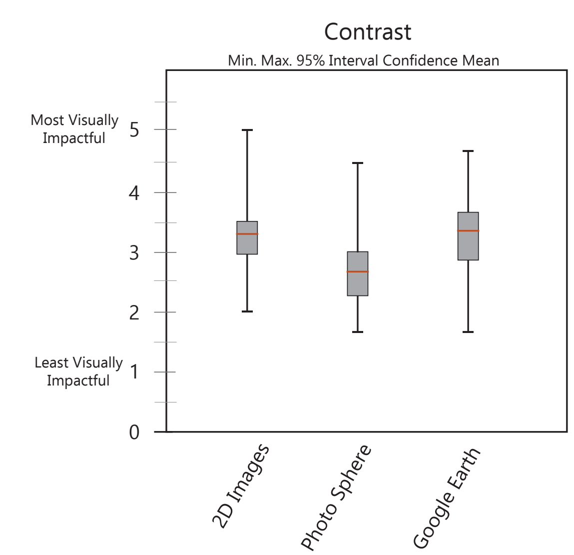


Figure 4.5: Contrast

At some of the distances tested, forms and lines become fuzzy while color and texture can become muddied.

Focal Points

The fourth variable analyzed was focal points, in which the participants rated how the proposed developed adds, subtracts, or alters

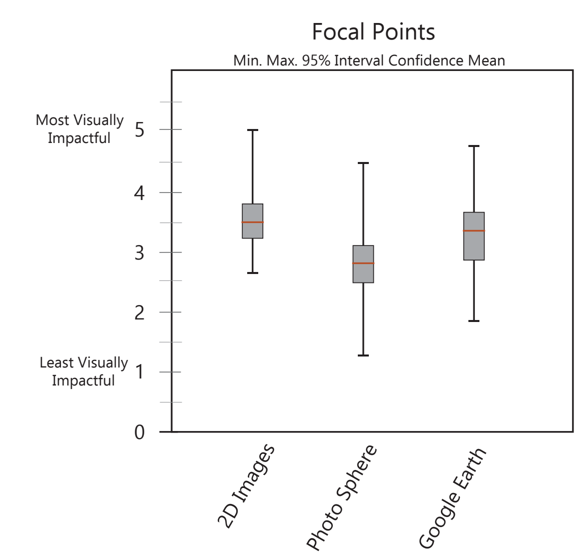


Figure 4.6: Focal Points

focal points within the view. The mean values once again show that photo sphere images (μ = 2.78) are, on average, rated lower than other visualization methods (2D images μ = 3.47; Google Earth μ = 3.28, refer to figure 4.6). The ANOVA analysis finds a positive confidence value with $p = 0.011$ and an F value of 4.873 as shown in table 4.5. The Tukey Post Hoc test confirms that there is a significant difference between photo sphere images and the other visualization media used in this study. The Post Hoc test also indicates that there is no significant differences between 2D image rating values and Google Earth when analyzing focal points. Similar to view extent, the difference in means values can be most likely attributed to panoramic nature of the photo sphere images compared to the focused 2D images. As the photo sphere images give you a 360° view from a viewpoint, there is simply more to observe as a viewer while a 2D image forces the viewer to focus on a smaller volume of space based around the proposal. Although Google Earth also provides a panoramic experience similar to photo spheres, the level of detail in which Google Earth represent vertical landscape elements such as vegetation makes the proposals more prominent within a view, drawing more attention.

Inconsistent Elements

The final variable analyzed was inconsistent elements. Inconsistent elements is intended to relate the visible area of proposal to the visible area of existing development, i.e. if a view has a lot of development, then the proposal has less of an impact on such view. Again, photo sphere images received a lower mean value (μ = 2.95) when compared to 2D images (μ = 3.23) and Google Earth (μ = 3.23, see figure 4.7). However, the ANOVA analysis found that there is no significant difference between the mean values ($F = 0.950$, $p = 0.392$, Table 4.6). No Post Hoc test was used with the inconsistent element variable as there was no significant differences discovered.

Focal Points

	N	Mean	Std. Deviation	Std. Error	95% Lower Bound	95% Upper Bound	Minimum	Maximum	Sig	*F*
2D Images	23	3.48	0.563	0.117	3.22	3.71	2.63	5		
Photo Sphere Images	23	2.78	0.796	0.166	2.44	3.13	1.25	4.5		
Google Earth	23	3.27	0.9	0.188	2.88	3.66	1.75	4.83		
Total	69	3.17	0.809	0.097	2.98	3.37	1.25	5.00	**0.011**	**4.873**

Table 4.5: Focal Points

Inconsistent Elements

	N	Mean	Std. Deviation	Std. Error	95% Lower Bound	95% Upper Bound	Minimum	Maximum	Sig	*F*
2D Images	23	3.23	0.804	0.168	2.88	3.58	2.13	5		
Photo Sphere Images	23	2.95	0.869	0.171	2.57	3.32	1.75	4.5		
Google Earth	23	3.23	0.755	0.157	2.9	3.56	2.25	4.625		
Total	69	3.14	0.81	0.096	2.94	3.33	1.75	5	**0.392**	**0.95**

Table 4.6: Inconsistent Elements

Demographic statistics

For further exploration, demographic data was collected from the participants to discover trends amongst age, gender, and visual impact assessment experience and their assessment ratings. The one-way ANOVA analysis was used to compare the different demographic sub-groups to their mean ratings.

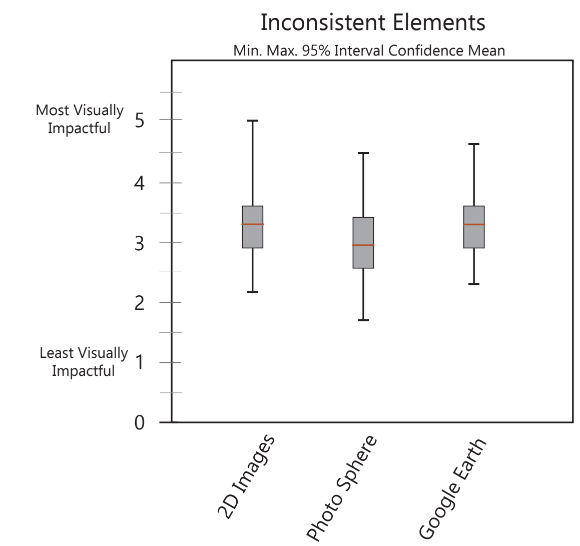


Figure 4.7: Inconsistent Elements

Gender

Ode *et al.* (2009) found that gender played a role in landscape aesthetic preference, and as such, gendered statistics were explored to find if gender affected visual impact assessment ratings. This study compared mean ratings between females and males based upon visualization media. Unlike Ode *et al.*, no significant differences were found between males and females in rating visual impacts with each having very similar mean rating values.

Age

To predict if age has an effect on the assessment ratings, a one-way analysis compared five age groups to the mean rating values given amongst the visualization media. The five age groups used in this assessment were, 18-30, 31-40, 41-50, 51-60, and 60 or older. The prediction for this analysis is that participants aged 51-60 and 60 or older would rate photo sphere images and Google Earth lower than the counterpart age groups. The one-way ANOVA analysis concluded that the age groups 51-60 and 60 or older typically rate visual impacts lower across all media, however, not to a level of significant difference. This indicates that age does not significantly affect visual impact assessment ratings as used in this method.

Experience

Those who are trained and have experience in assessing landscape visuals typically conduct visual impact Assessments. However, Churchward *et al. (2013)* argue that public participation is necessary conducting a VIA as the public and professionals view landscape differently, as concluded numerous studies (Strumse, 1996; Van Den Berg *et al.,* 1998, and Coeterier, 2002). In this study, the participants were asked about the number of visual impact assessments that they have had a role in. For this study, the number of visual impact assessment participated in defines their experience. From the data, three experience groups were formed; little to no experience (those who claimed to have participated on less than 3 VIAs), some experience (participants on 4-10 VIAs), and experienced (those whom have work on 10+ VIAs). Contrary to most research, this study found that there is no significant difference between unexperienced and experienced participants. However, due to the limited number of participants, further exploration is needed to accurately substantiate this claim.

Survey Feedback

At the conclusion of the assessment, participants were asked their opinions on the survey rating criteria and their view on immersive technology's role in visual impact assessments. Two concluding questions were asked, the first asked if they (the participants) think that immersive technology could play a role in visual impact assessments? The second asked if they thought the survey design worked well, as it has not been validated and is still developing for professional use.

Overall, more than 37% of participants believe that immersive technology will soon replace the use of 2D images when the technology becomes more integrated and optimized. Participants felt that with better image quality and more viewpoint/site knowledge (number of impacted people, site history, etc.) photo sphere images have huge potential. However, some stated that they believed that photo sphere and Google Earth would require more work and would receive similar results as to 2D images.

The final question allowed that participants to give feedback on the survey design, as it has yet to be validated. Participates stated that they felt that Google Earth severely lacked in presenting details to the assessors and that it should have been changed for the study. Insufficient levels of detail can be most likely attributed to the remoteness of the viewpoint locations. Many of the lands in which VIAs are being conducted are located in remote areas, and the landscape representation used in this study would be consistent to most landscapes used in future studies. Interestingly, the participants felt as if Google Earth would be judged differently but from the results it can be deduced that they were rated consistently with 2D images.

5 Discussion

Figure 5.1: Cover Image

Discussion

Overview of Results

Most visual impact assessment practices require on-site observations in order to make informed land planning decisions. However, natural, climatic, and anthropocentric conditions often make coordinating an assessment difficult. Visualization technology can now provide immersive, 360° experiences of spaces, allowing assessments to be made off-site. To test new visualization media, visual impact assessment results were compared to the results of the traditional practice of using 2D images. Overall, the study rejects the hypothesis of consistent ratings across visualization media, finding that using a photo sphere image for conducting a visual impact assessment will typically allow for more built development to occur than using a 2D image or Google Earth.

Further analysis was conducted among the variables used to get the overall scores. The five variables used to rate* each assessment were; the change of landscape character, view extent, contrast, focal points, and inconsistent elements. Photo sphere images consistently rated lower in all the categories when compared to 2D images and Google Earth. Predictions as to why photo sphere images were rated lower were postulated.

Challenges

Being on site allows for the experiential qualities of nature to influence land planning decisions. In the ideal scenario, on-site assessment would be compared to visualization technologies in visual impact assessments. However, time and the ability to gather a sufficient number of professionals for site visits prevented the ability to compare on-site results to immersive visualization methods.

Larger Context

The results of the survey feedback and the study show that professionals are ready and willing to use immersive visualization media for conducting visual impact assessments, however, the technology is not quite there yet. With greater optimization and multimedia platform support, the technology tested could be a viable surrogate for 2D images. Further research could be conducted when better photo sphere image platforms develop that can distribute higher resolution images. Wearable gear, such as virtual reality headsets could be tested as tools for visual impact assessments, as well as augmented reality programs.

Reflections

Limitations

Three primary limitations can be found in this study; limited number of participants, limited ecoregion, and the survey design. The first and possibly most impactful limitation is that a smaller sample size was used in this study. In total, 23 participants completed the survey. Increasing the number of participants could create more statistically representative results. Although some participants stated that they have partook in zero visual impact assessments, the population used to take the survey all have interest, and work with, landscape visuals. Thus, results from this survey might not be representative of all populations, particularly those that do not work with landscapes.

As this study tests visual impacts within Texas grasslands and pastures, results may not be applicable in other landscape ecoregions. Predicting visual impacts is solely dependent on site-specific characteristics. Each view tested in a visual impact assessment is unique to that landscape and each landscape differs from all others. Landscapes can vary greatly from the ones used in this study in terms of vegetation, landform, visibility, etc., so it cannot be assumed that the results of this study will hold true in all landscapes.

Professionals in the field of visual resource management designed the rating criteria used in the survey, however, it is still in development and has yet to be used in a visual impact assessment. The use of this survey design allowed for comments and feedback from professionals to further refine how the criteria is rated. Existing VIA practices were not used in this study because no method found would fully test new visualization technology to the detail needed for the study.

The survey was designed on a platform that makes the process more convenient for the participant. However, the survey program used, Qualtrics, does not have the ability to embed the photosphere images used in this survey. A work around was completed by exporting the images to minute long videos. The process used to convert the image to a video down sampled the images, resulting in a loss of detail for the videos. Results of the photo sphere images could differ is utilizing the original image quality.

Design Process and Future Research

The design process used in this survey was restricted to the requirements set forth by Kansas State University's Graduate School timeframe. In ideal conditions and with greater resources, the design of this study would have varied greatly. In the ideal study, on-site observations would have been compared to new visualization methods rather than 2D images. It would be interesting to see if 'fully immersive' on-site observations would differ from digitally immersive environments. Using on-site observations as a comparison would give the most representative results of perceived impact.

However, to get fully represented results, a larger and more diverse participant population would be needed. In getting a larger and more diverse population, it would be interesting to observe perceived impact ratings and demographic data. Would gender influence rating? Would experience? Is the technology efficient across all age generations? Do participants rate impacts differently based upon their geographic region?

The specific survey used to judge visual impacts in this study is currently in development and as such, has not been applied before. Further research could aim to rigorously test each of the rated variables used and how people respond to them. More testing is needed to validate the survey method.

It would be interesting to test this process in different geographic regions. Having traveled to Arches National Park and Canyonlands National Park, would the verticality of the landforms be well rendered in both photo sphere images and Google Earth or would the sheer beauty of the landscape be captured in the 2D images? Would areas with higher detail in Google Earth models be rated differently than landscape with few details? It would be interesting to look into the degree that the perceived cultural significance influences the visual impact ratings. Would an image in a national park with signage describing a view increase ones perceived cultural value and thus influence their impact rating? There are many opportunities to further explore variables that influences perceived visual impacts outside of what's in any one view.

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A
Appendix

Figure A.1: Cover Image

Viewpoint 1: 2D Image

Presented is a collection of all the images used in the study. Photo sphere images and Google Earth models were displayed through digital media during the survey that allowed for a 360 degree experience. However, this can not be easily translated into a two dimensional format. As such, photo sphere images are displayed in this book as they would normally be displayed in a 2D format, with the addition of a smaller "rear" view display. Google Earth images were captured to show the development.

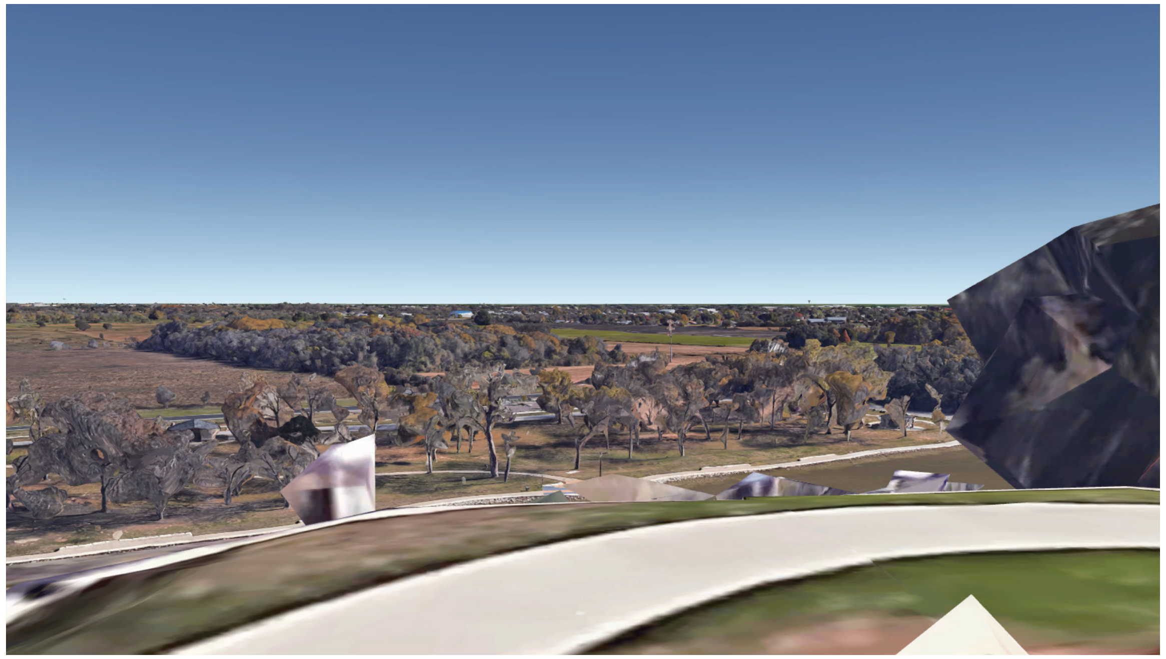
Figure A.1.1: Viewpoint 1 - 2D Image Before and After

Viewpoint 1: Photo Sphere Image

Figure A.1.2: Viewpoint 1 - Photo Sphere Image Before and After

Reverse View

Viewpoint 1: Google Earth



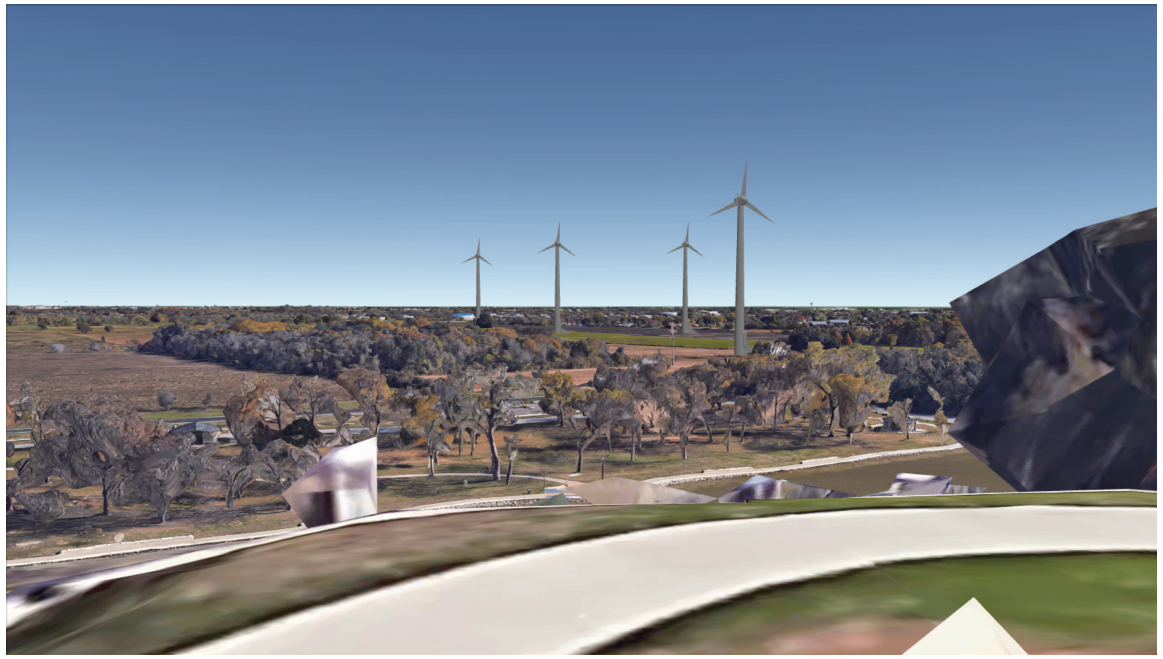
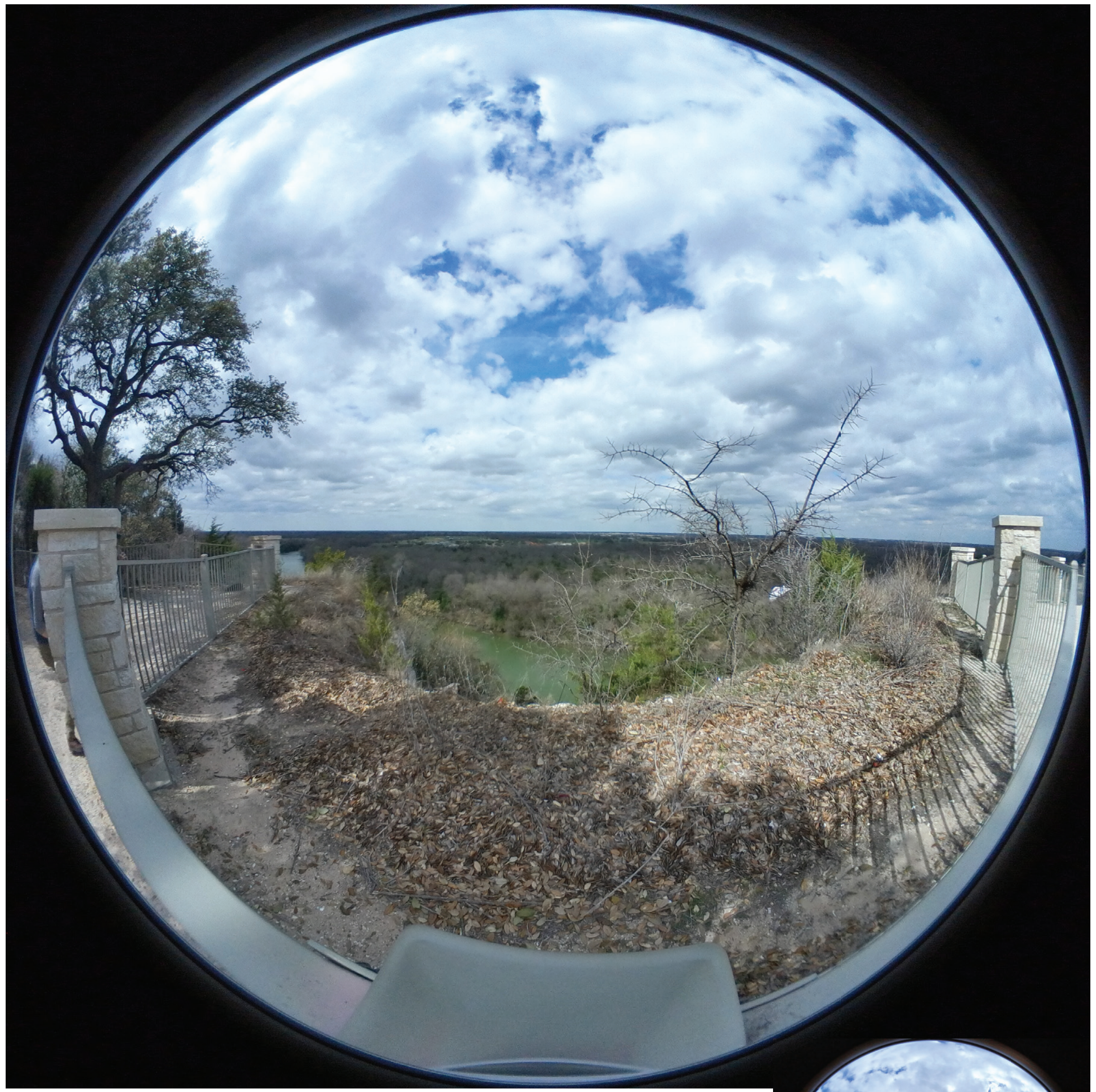


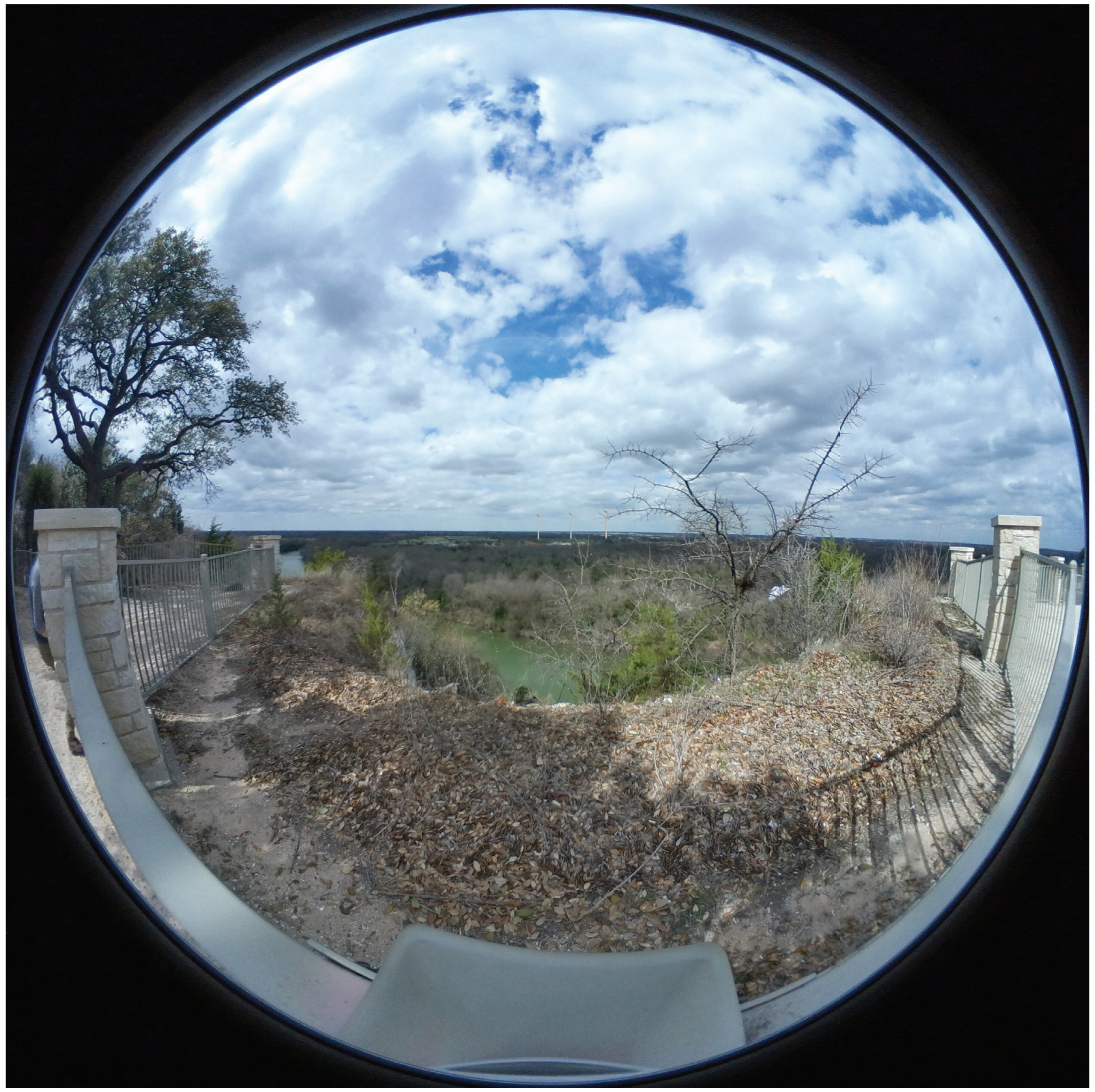
Figure A.1.3: Viewpoint 1 - Google Earth Image Before and After

Viewpoint 2: 2D Image

Figure A.2.1: Viewpoint 2 - 2D Image Before and After

Viewpoint 2: Photo Sphere Image





Reverse View

Figure A.2.2: Viewpoint 2 - Photo Sphere Image Before and After

Viewpoint 2: Google Earth

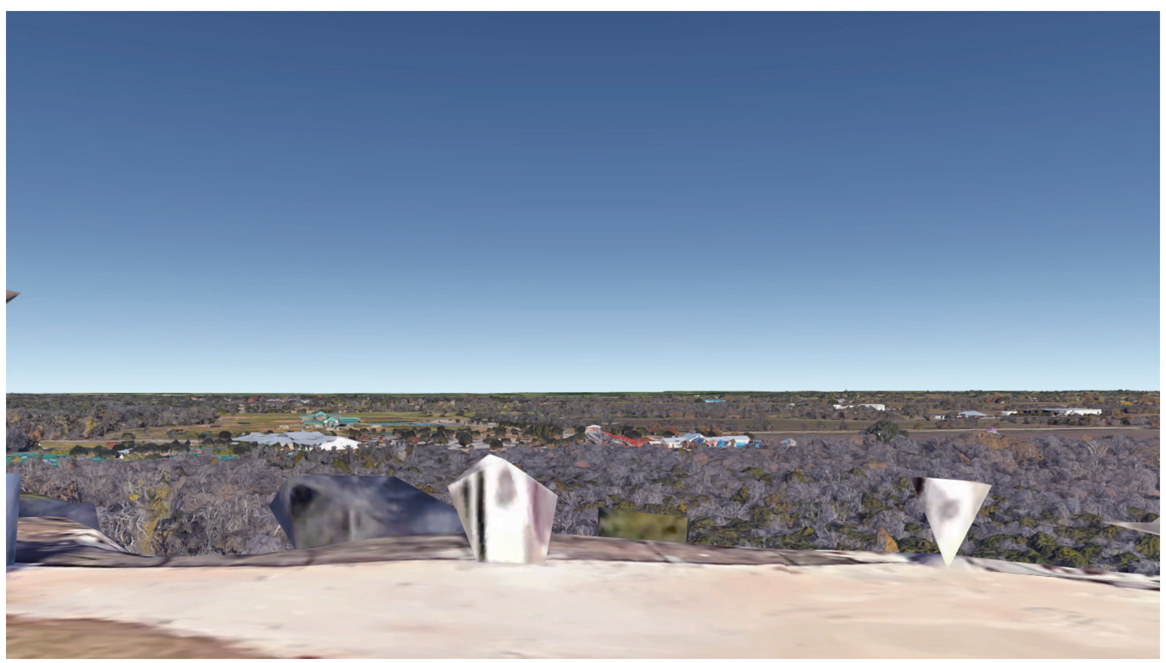


Figure A.2.3: Viewpoint 2 - Google Earth Image Before and After

Viewpoint 3: 2D Image

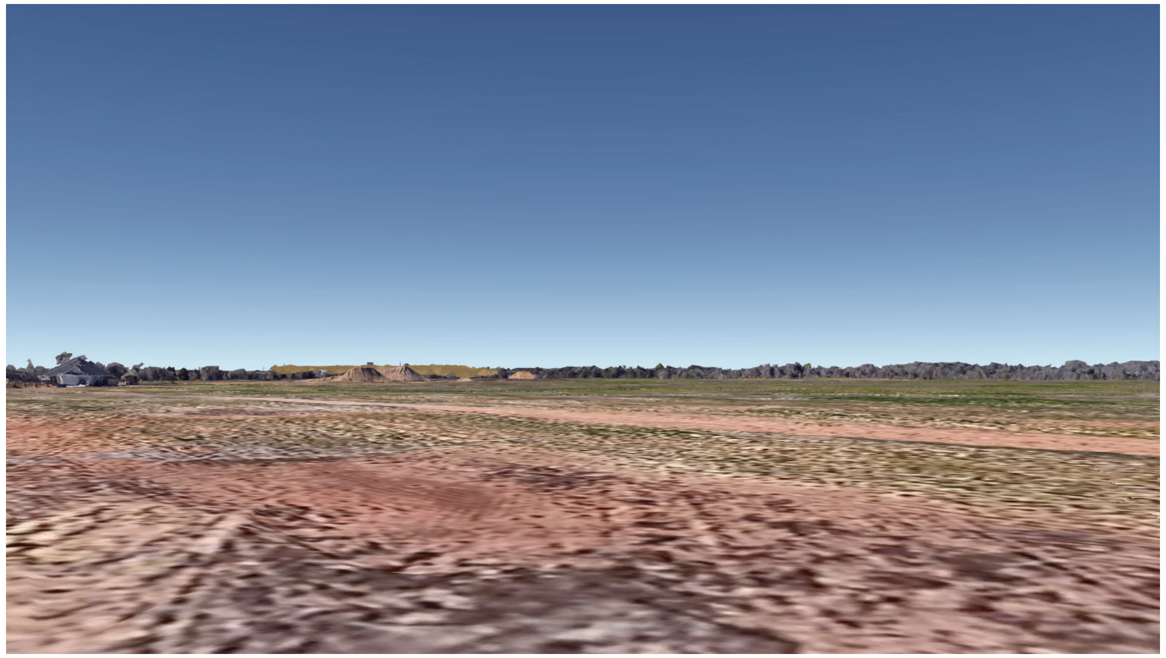
Figure A.3.1: Viewpoint 3 - 2D Image Before and After

Viewpoint 3: Photo Sphere Image

Reverse View

Figure A.3.2: Viewpoint 3 - Photo Sphere Image Before and After

Viewpoint 3: Google Earth



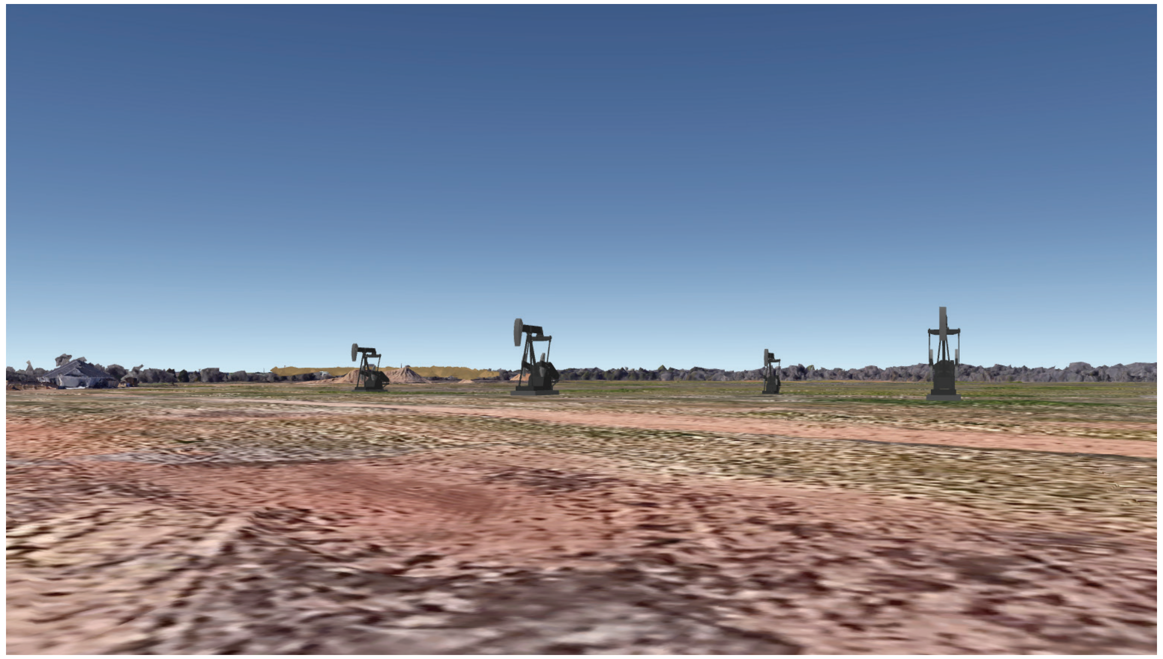
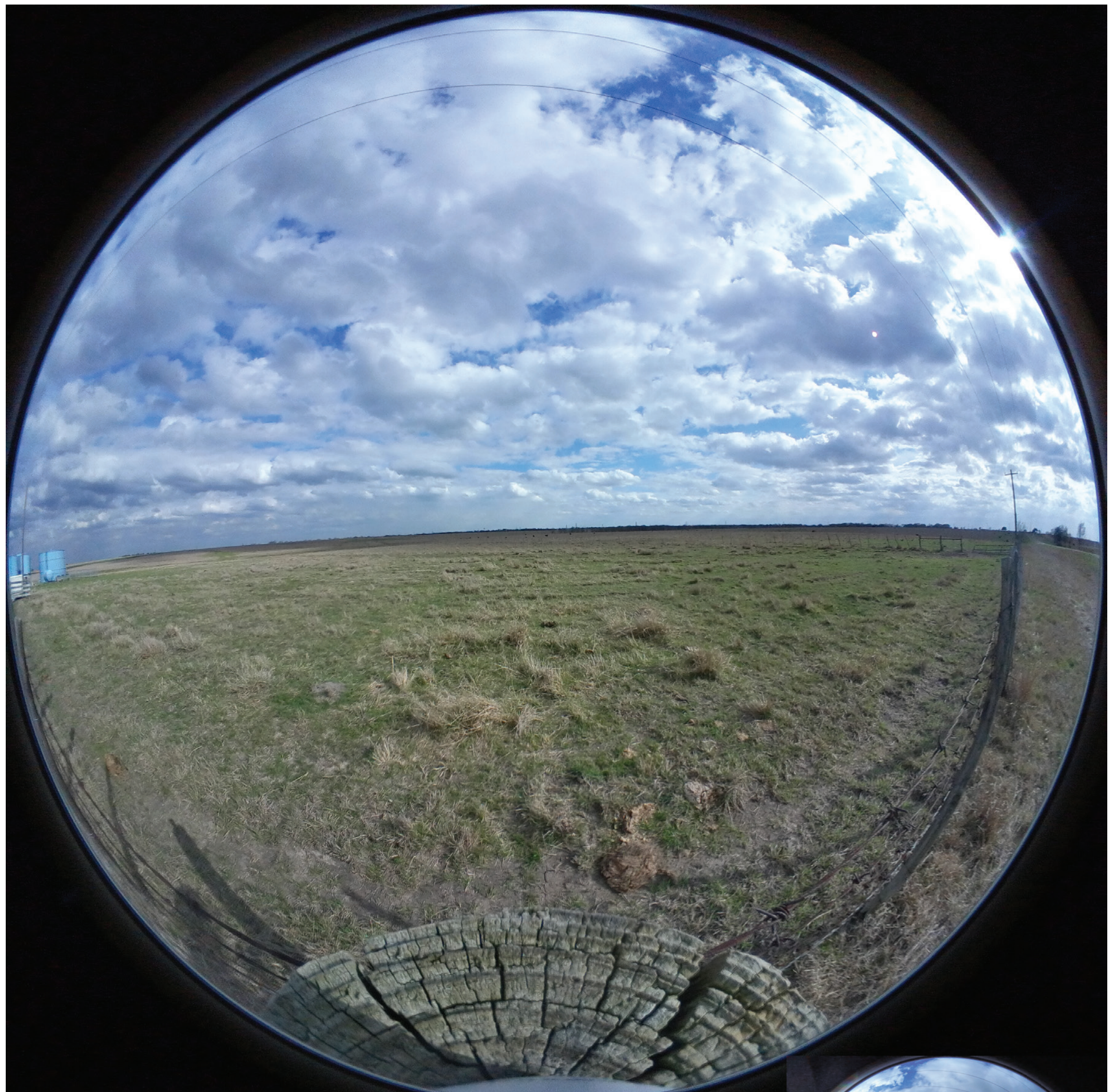


Figure A.3.3: Viewpoint 3 - Google Earth Image Before and After

Viewpoint 4: 2D Image

Figure A.4.1: Viewpoint 4 - 2D Image Before and After

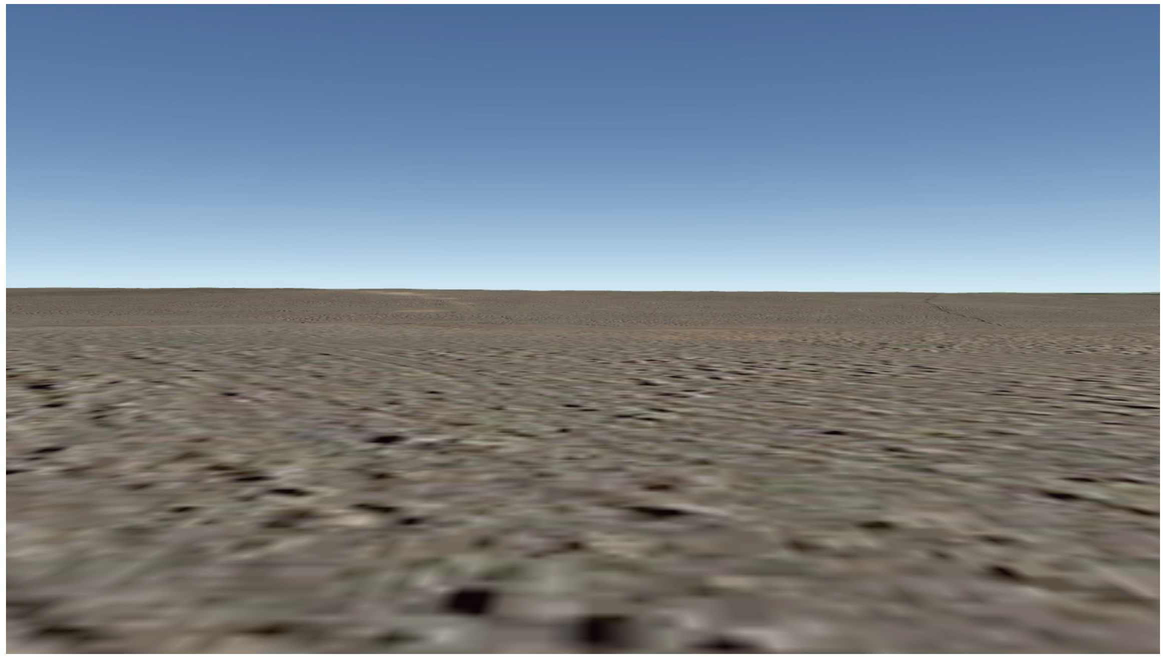
Viewpoint 4: Photo Sphere Image



Reverse View

Figure A.4.2: Viewpoint 4 - Photo Sphere Image Before and After

Viewpoint 4: Google Earth



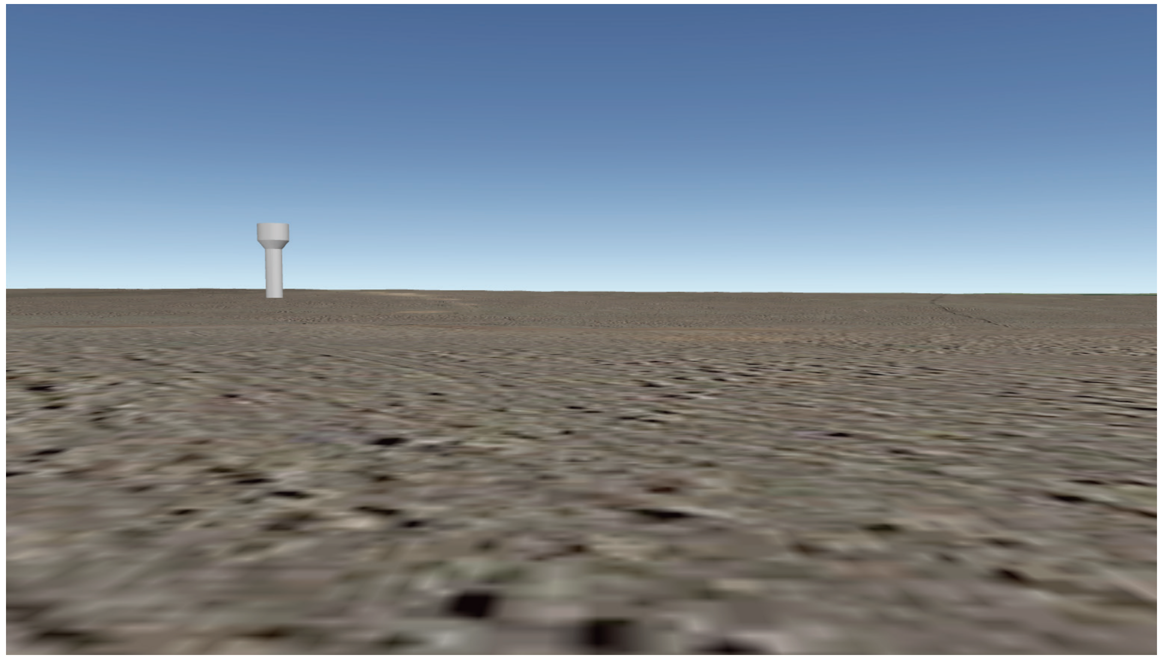


Figure A.4.3: Viewpoint 4 - Google Earth Image Before and After

Viewpoint 5: 2D Image

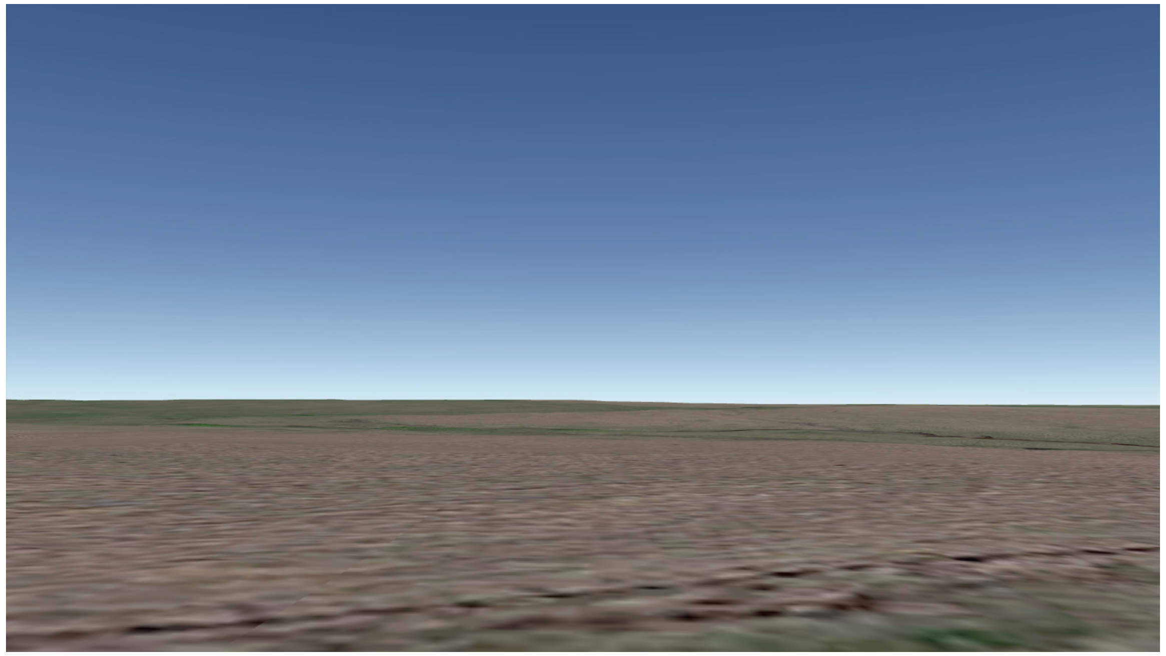
Figure A.5.1: Viewpoint 5 - 2D Image Before and After

Viewpoint 5: Photo Sphere Image

Figure A.5.2: Viewpoint 5 - Photo Sphere Image Before and After

Reverse View

Viewpoint 5: Google Earth



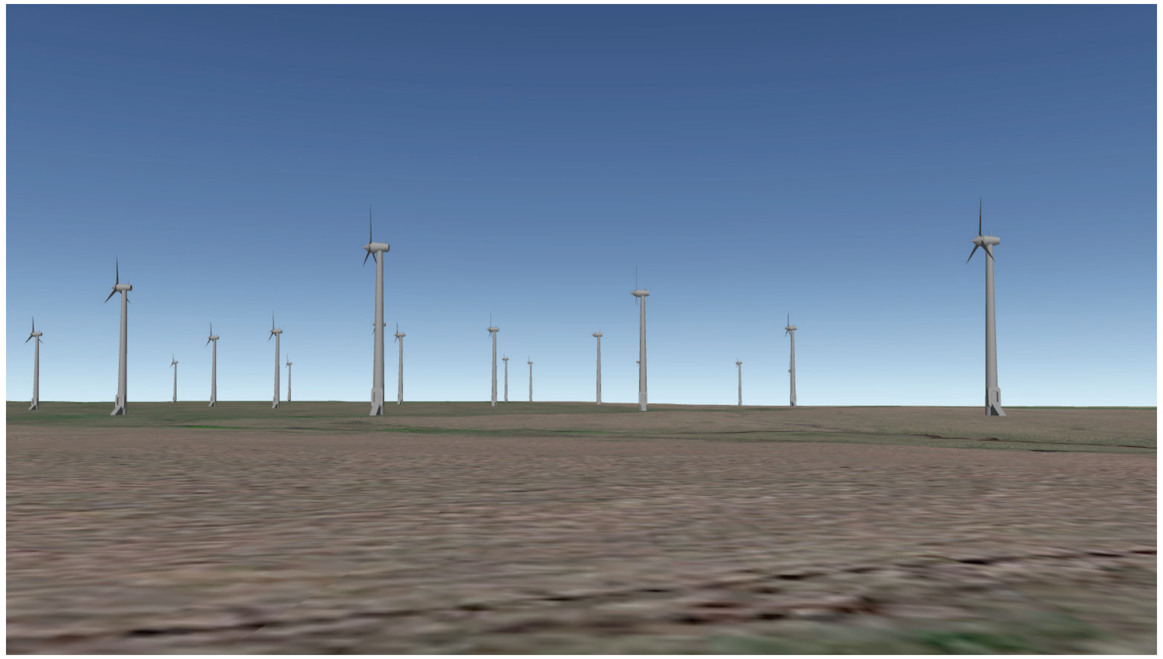


Figure A.5.3: Viewpoint 5 - Google Earth Image Before and After

Viewpoint 6: 2D Image

Figure A.6.1: Viewpoint 6 - 2D Image Before and After

Viewpoint 6: Photo Sphere Image

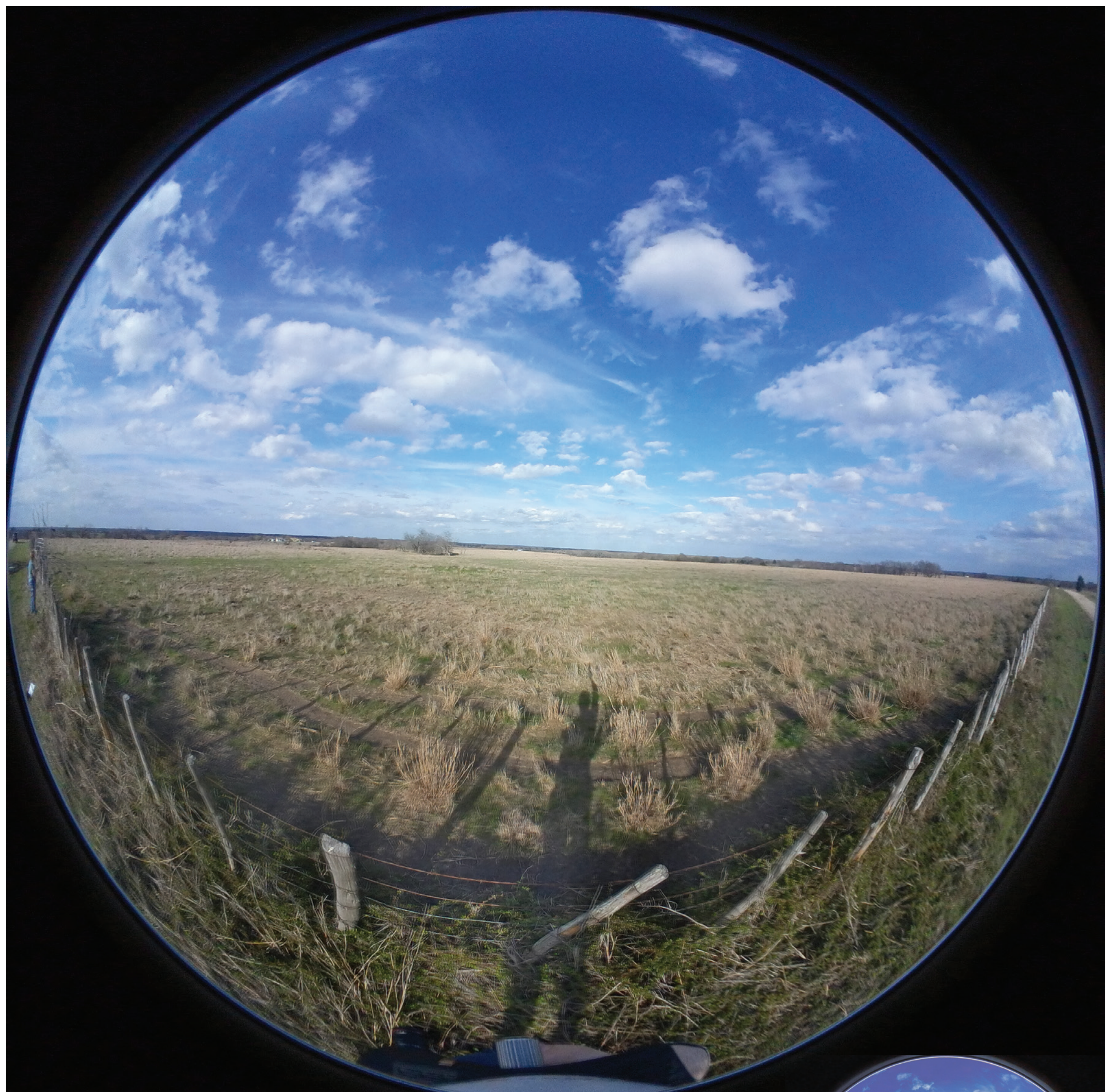


Figure A.6.2: Viewpoint 6 - Photo Sphere Image Before and After

Reverse View

Viewpoint 6: Google Earth

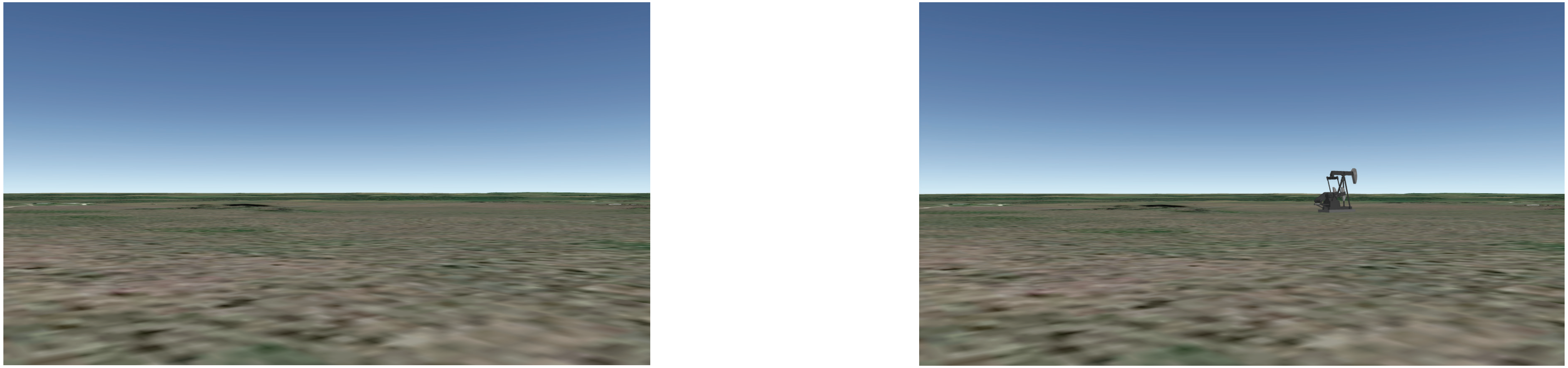


Figure A.6.3: Viewpoint 6 - Google Earth Image Before and After

Viewpoint 7: 2D Image

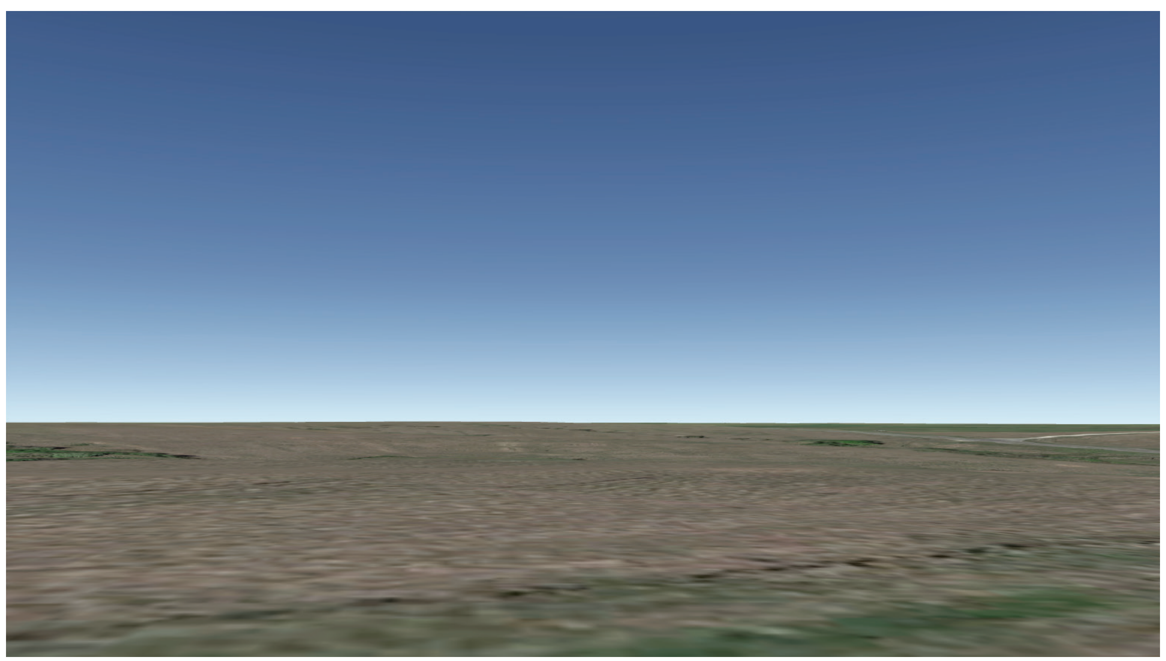
Figure A.7.1: Viewpoint 7 - 2D Image Before and After

Viewpoint 7: Photo Sphere Image

Reverse View

Figure A.7.2: Viewpoint 7 - Photo Sphere Image Before and After

Viewpoint 7: Google Earth



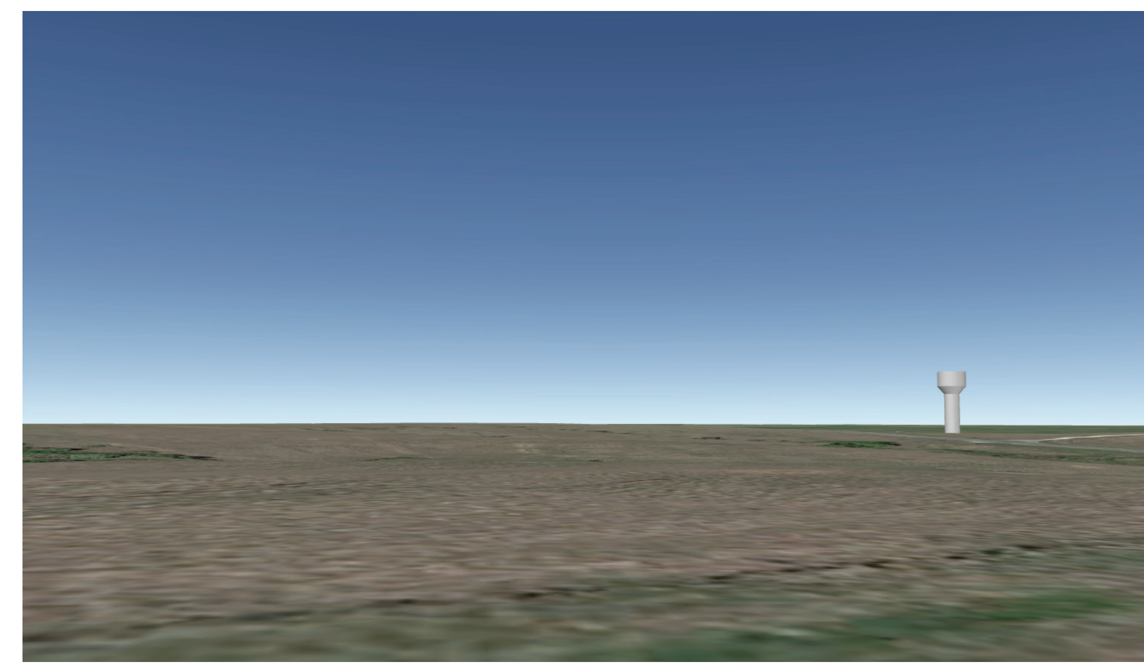


Figure A.7.3: Viewpoint 7 - Google Earth Image Before and After

Viewpoint 8: 2D Image

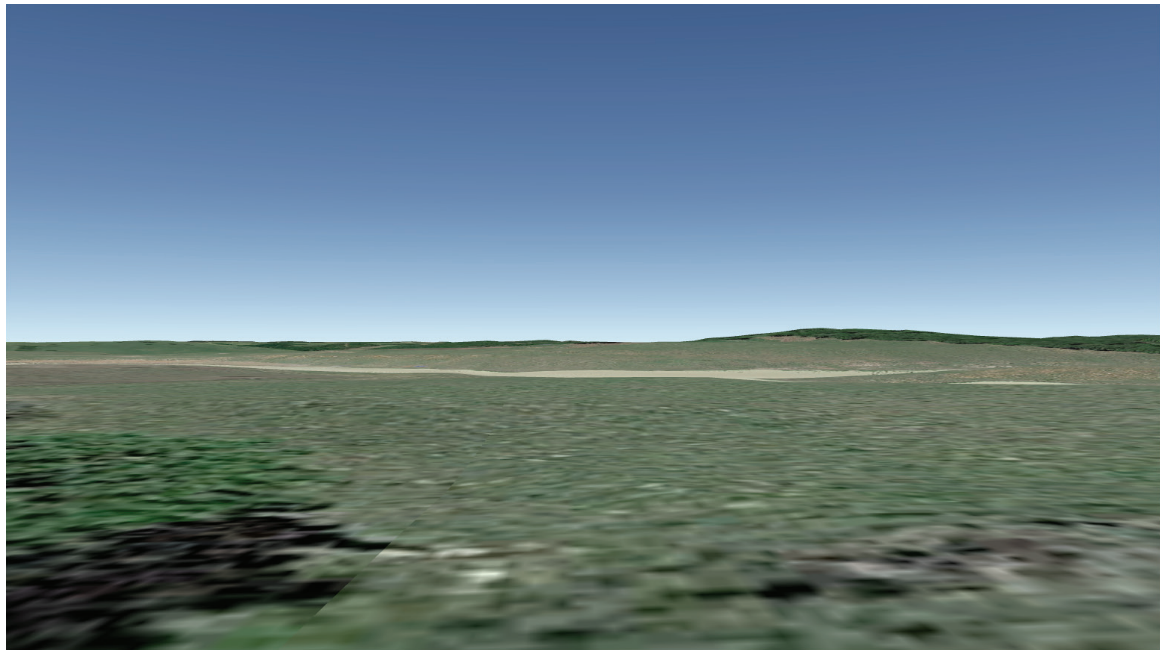
Figure A.8.1: Viewpoint 8 - 2D Image Before and After

Viewpoint 8: Photo Sphere Image

Figure A.8.2: Viewpoint 8 - Photo Sphere Image Before and After

Reverse View

Viewpoint 8: Google Earth



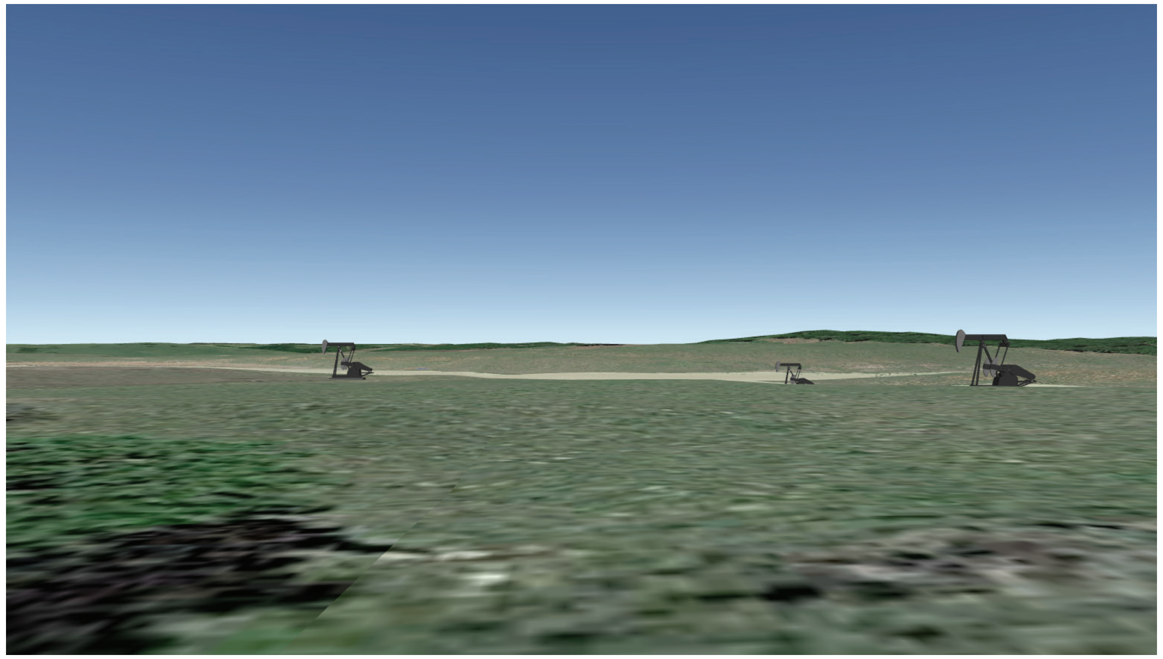


Figure A.8.3: Viewpoint 8 - Google Earth Image Before and After

B Appendix

Figure B.1: Cover Image

Survey

Instructions

Thanks you for participating in this study.

The purpose of this study is to explore immersive visualization tools in visual impact assessments. As traditional photographs give a limited angle of the proposal and the site, newer immersive technologies can give a full 360° experience. In this survey, 2D images are going to be compared to 360 photo sphere images and Google Earth ground level view. As participants in this study, you will be asked to conduct 24 visual impact assessments.

Before you begin please have the following prepared:
It is advised to have the rating criteria readily available for reference purposes. Rating criteria
The Google Earth file used in this study can be found here: Visual assessment
Full Survey instructions can be found here: Survey instructions

Agree to Participate

By completing the action below, you are agreeing to participate in this study. More information can be found here: Informed consent

Background Information

What is you gender?

- ○ Male
- ○ Female
- ○ Other
- ○ Prefer not to say

What is you age?

- ○ 18-30
- ○ 31-40
- ○ 41-50
- ○ 51-60
- ○ 65+

Which sector(s) have you worked in?

- ☐ Public
- ☐ Private
- ☐ Academic
- ☐ Other

Which geographic regions have you worked in?

- ☐ Appalachian/North East
- ☐ Plains and Grasslands
- ☐ Pacific Northwest

Figure B.2: Qualtrics Survey

- ☐ South West
- ☐ Pacific Coast
- ☐ Rocky Mountain
- ☐ Other

What is your area of study?

About how many visual impact assessments have you participated in?

What visual impact assessment methods are you accustomed to?

8B

View Extent

Contrast

Focal Points

Inconsistent Elements

6C

Please refer to VP6 in the Google Earth document for the following assessment.

Rate the visual impact based on the following factors

Reference here for how to rate each factor

	Least Visually Impactful			Most Visually Impactful		
	0	1	2	3	4	5
Character Type						
View Extent						
Contrast						
Focal Points						
Inconsistent Elements						
View Composition						

After Survey Responses

Which media type did you think you spent the most time viewing?

- 2D Images
- Photo Sphere Images
- Google Earth

Do you think immersive technology can play a role in visual impact assessments?

As this method has not been used before, how well do you think it works as a visual impact assessment tool?

Any other comments you wish to leave about the method or the study.

Character Type:

- What is the existing Landscape Character? Agriculture/Natural/Developed/Industrial
- How will the project alter the existing landscape character?

To what degree does the proposal fit in the overall landscape character type?

View Extent:

- How visible is the project?
- Is the project hidden behind landscape elements?
- What distance zone is the project located in?

How much of the view does the project encompass?

Contrast:

- How well do forms change from the existing view to the proposed project?
- How well are proposed lines replicated from existing lines in the view?
- How harmonious are colors from the proposed project in relation to the landscape surrounding?
- How do textures of the landscape match textures in the project?

To what degree does the project contrast the landscape?

Focal Points:

- To what extent are new focal points added to the view?
- Will new focal points be considered to have a positive or negative impact on the view?
- Do new focal points compete with exiting focal points?
- How does the placement of the proposal affect existing focal points?

To what extent does the proposal affect focal points in the view?

Inconsistent Elements:

- How much additional human-intervention elements are being added to the view?
- How much of the view do all inconsistent elements (including the proposal) occupy?
- How visually dominant are inconsistent elements?

To what extent do the Inconsistent elements detract from the view?

C Appendix

Figure c.1: Cover Image

IRB Approval

KANSAS STATE UNIVERSITY | University Research Compliance Office

TO: Dr. Timothy Keane
Landscape Architecture/Regional and Community Planning
2007 Seaton Hall

Proposal Number: 9180

FROM: Rick Scheidt, Chair
Committee on Research Involving Human Subjects

DATE: 02/28/2018

RE: Proposal Entitled, "Visual Impact Assessments in Virtual Environments: A test of validity between virtual environments and on-site observations"

The Committee on Research Involving Human Subjects / Institutional Review Board (IRB) for Kansas State University has reviewed the proposal identified above and has determined that it is EXEMPT from further IRB review. This exemption applies only to the proposal - as written – and currently on file with the IRB. Any change potentially affecting human subjects must be approved by the IRB prior to implementation and may disqualify the proposal from exemption.

Based upon information provided to the IRB, this activity is exempt under the criteria set forth in the Federal Policy for the Protection of Human Subjects, **45 CFR §46.101, paragraph b, category: 2, subsection: ii.**

Certain research is exempt from the requirements of HHS/OHRP regulations. A determination that research is exempt does not imply that investigators have no ethical responsibilities to subjects in such research; it means only that the regulatory requirements related to IRB review, informed consent, and assurance of compliance do not apply to the research.

Any unanticipated problems involving risk to subjects or to others must be reported immediately to the Chair of the Committee on Research Involving Human Subjects, the University Research Compliance Office, and if the subjects are KSU students, to the Director of the Student Health Center.

203 Fairchild Hall, Lower Mezzanine, 1601 Vattier St., Manhattan, KS 66506-1103 | 785-532-3224 | fax: 785-532-3278
comply@k-state.edu | k-state.edu/research/comply

Figure C.2: IRB Approval Form