Appendix F. Recreation

Draft Kansas River Reservoirs Flood and Sediment Study

October 2023

U.S. Army Corps of Engineers Kansas City District Recreation Evaluation -Existing Conditions and FWOP

Kansas River Reservoirs Flood and Sediment Study (Watershed Study)

10/30/2023

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1.0. Introduction

The Kansas River Reservoirs Flood and Sediment Study (Watershed Study) will focus on U.S. Army Corps of Engineers (USACE) and U.S. Bureau of Reclamation (USBR) reservoirs (see Table 1) and river reaches in the watershed. The Kansas River Basin includes 7 USACE reservoirs and 10 USBR reservoirs. USACE projects in the Kansas River Basin include Clinton Lake, Kanopolis Lake, Milford Reservoir, Perry Lake, Tuttle Creek Lake, and Wilson Lake in Kansas and Harlan County Lake in Nebraska. USBR reservoirs include (all in Kansas): Cedar Bluff Reservoir, Lovewell Reservoir, Kirwin Reservoir, Webster Reservoir, Waconda Lake/Glen Elder Dam, Keith Sebelius Lake/Norton Dam, Hugh Butler Reservoir/Red Willow Dam (Nebraska), Harry Strunk/Medicine Creek Dam (Nebraska), Enders Reservoir (Nebraska), Swanson Reservoir/Trenton Dam (Nebraska).

Public lands that provide recreation opportunities are relatively rare in Kansas, with privately-owned lands accounting for 98.4% of the land in Kansas. State and federal lands account for approximately 1.3% of total lands in the state, and only a portion of these state and federal lands are associated with recreational parks and areas (Headwaters Economics, 2020). State-owned and controlled lands for recreation account for only 0.7% of lands in the state (KDWP, 2023, pers. com. with S Adams). Because of the scarcity of federal and state public lands for recreation in Kansas, it is imperative that these lands are protected and managed to promote sufficient recreational opportunities to meet the needs of residents and visitors to the state.

The assessment of recreation focuses on how future conditions, including sediment, water quality, and drought, within the Kansas River Basin affect recreation, and where possible, quantifying these economic impacts. Recreational activities in the Kansas River Basin improve the quality of life for the citizens of Kansas and neighboring states, increase the value of natural resources, draw visitors to the areas, and contribute to the regional economy. For the purposes of this study, the focus will be on the USACE/USBR areas in Kansas listed above, the Kansas River mainstem, along with Harlan County Reservoir in Nebraska.

Recreational opportunities are currently available in the Kansas River Basin, and a detailed evaluation and analysis of projected changes in the Kansas River Basin is necessary to document the value of recreation to Kansas. Water-based recreational opportunities are threatened by low and high-water levels, reservoir sedimentation, poor water quality, diminished in-stream flows, and invasive species.

Recreation areas are grouped by Regional Planning Areas (RPAs) in Kansas and one Nebraska reservoir, Harlan County Lake (Table 1), with existing conditions and future without project (FWOP) conditions described for each reservoir and the Kansas River mainstem. The existing conditions sections include an overview of the recreation areas of the 13 reservoirs (USACE/USBR) and the Kansas River mainstem that are the focus of the recreation assessment for the Watershed Study in the Kansas River Basin.

Kansas Regional	Smoky Hill Saline	Solomon-Republican	Nebraska			
Planning Area	Regional Planning Area	Regional Planning Area	Reservoirs			
Clinton	Cedar Bluff*	Keith Sebelius Lake (Prairie Dog State Park)*	Harlan County			
Milford	Kanopolis	Kirwin*				
Perry	Wilson	Lovewell*				
Tuttle Creek		Waconda Lake/Glen Elder Dam*				
Kansas River Mainstem		Webster*				

Table 1. Regional Planning Areas, Reservoirs, and Kansas River Mainstem

*Denotes USBR Reservoirs

**Throughout the document lake and reservoir are used interchangeably

2.0. Methodology

The assessment of recreation includes both qualitative and quantitative methods. The methods used are described below.

2.1. Qualitative Assessments

Qualitative methods were used to assess the effects of harmful algal blooms, water quality issues, habitat availability, and changes to reservoir fisheries on recreation at all of the reservoirs. The information used to qualitatively assess recreation was based on research, documents (e.g., Kansas State Wildlife Action Plan), information from subject matter experts, and data generated prior to the study or during the study (e.g., projected sedimentation in reservoirs; assessments of reservoir fisheries). FWOP impacts related to flooding repair and clean-up costs are discussed qualitatively, based on past impacts associated with the 2019 flood.

Because USACE sediment modeling indicated very few impacts to future sediment conditions and because no hydrology and hydraulics (H&H) modeling was conducted for Cedar Bluff, Keith Sebelius (Prairie Dog State Park), Kirwin, Webster, and Lovewell reservoirs, FWOP recreation impacts from sediment and changes in water surface elevations were evaluated qualitatively for these reservoirs. In addition, Harlan County reservoir in Nebraska is affected be sediment deposition in the coves of the reservoir, although the impacts to visitation and economic benefits are described qualitatively. These recreation evaluations were based on resource conditions, such as available information and resource reports on sediment, hydrology, and other conditions. Many of the western reservoirs do not have sufficient inflows for there to be notable sediment impacts.

All reservoirs in the Kansas River Watershed will likely experience increasing effects of aging. Future water quality within the Kansas River watershed lakes is dependent on multiple influencing factors, some of which are challenging to predict and/or estimate. It can be assumed that continued, and increasing fertilizer use, will continue to influence the water quality of runoff, groundwater, streams, and lakes. Approximately 40% of the total watershed area is classified as Grassland/Herbaceous and Pasture/Hay, much of which is used as rangeland/stock areas for livestock in the watershed. The Kansas Department of Agriculture (2021) publishes total numbers of livestock (cattle, sheep, hogs), and increasing trends in the numbers of animals that require feed and produce increased quantities of manure, indicate the potential for worsening water quality in downstream lakes.

Continued sediment loading will diminish storage capacity, deliver increased quantities of nutrients and pollutants, and compound effects of eutrophication. Continued and enhanced water quality impairment may be expected at all of the reservoirs in the basin. Consistent with existing conditions, storm events generating high run-off volumes will continue to transport the majority of sediment and nutrient loads to the reservoirs. Deposited and suspended sediments affect aquatic habitat and life, contributing to reduced abundance and diversity via smothered spawning sites, inhospitable macroinvertebrate habitat, increased turbidity, reduced light availability, inhibited phytoplankton and macrophyte growth, diminished sight and filter-feeding, and water temperature effects.

The nutrients nitrogen and phosphorus are abundantly available throughout the watershed. A watershedwide pattern of increasing in-lake total phosphorus concentrations suggests potential for continued eutrophication (high algal productivity) at watershed reservoirs. Phosphorus is often considered a nutrient that limits primary productivity (e.g., phytoplankton, aquatic plants), although nutrient limitation of phytoplankton growth is dependent on species and may vary depending on time and location. Too much phosphorus can cause increased growth of algae and aquatic plants, which can result in decreased levels of dissolved oxygen, a process called eutrophication. Observed decreasing total nitrogen to total phosphorus (TN:TP) ratios may indicate an enhanced opportunity for seasonal harmful algal bloom (HAB) – algal blooms that produce toxins detrimental to human and animal health – issues as some flourish under conditions with elevated phosphorus availability and water temperature (Appendix G).

2.2. Quantitative Assessments

Quantitative approaches were developed to evaluate economic effects to recreation associated with changes in water surface elevations and sediment deposition under the FWOP. Specifically, quantitative approaches include an assessment of how water surface elevations, river flows, and sediment deposition affect visitation, and subsequently consumer surplus and regional economic benefits at six USACE reservoirs (Clinton, Perry, Tuttle Creek, Milford, Wilson, and Kanopolis reservoirs), one USBR reservoir (Waconda), and the Kansas River mainstem. These quantitative approaches are described in this section.

The quantitative models were developed to help answer questions, such as:

- Are there reservoirs more at risk from variations in water surface elevations affecting recreation relative to others?
- What kinds of visitors will be impacted at specific reservoirs?
- Where could future efforts prioritize work to maintain recreation access (e.g., extend boat ramps at a specific reservoir; sediment management; improved flood management)?

Flooding, drought, and reservoir sedimentation are the stressors with the highest risks to recreation economically from losses in recreational opportunities, damage, repair costs, lost revenues, or lost jobs. With changes in water surface elevations, the quantitative models can estimate how visitation, consumer surplus and economic benefits in adjacent communities and the state would be impacted, providing useful and vital information for state resource agencies (e.g., Kansas Department of Wildlife and Parks [KDWP] and Kansas Water Office [KWO]).

2.2.1. Sediment and Water Surface Elevation Modeling

An initial step in the evaluation process was to identify the reservoirs to be further analyzed with regard to recreation impacts in the Watershed Study. This is often based on the availability of certain types of information. The sedimentation modeling conducted by the USACE sediment engineers provides an indication of the potential future impacts to recreation (Appendix D). USACE sediment engineers provided digital mapping of the surface area or contour of the multipurpose pool of the reservoirs as well as digital elevation maps under the FWOP conditions. These digital elevation maps were overlaid with maps of the recreation infrastructure at each of the USACE reservoirs and the USBR reservoir for each of the FWOP sedimentation scenarios. The reservoir depth maps were used to assess how water-based access at recreation areas would be affected at the lakes impacted by sediment deposition.

Based on input from the project staff and a review of the H&H sediment modeling, it is likely that future impacts to visitation could potentially occur from increased sediment deposition at Tuttle Creek, Perry, Kanopolis, Waconda, and Harlan County. These lakes are assessed in terms of how sediment conditions could affect visitation in the FWOP and subsequently consumer surplus and regional economic benefits.

Future sediment conditions will affect reservoir operations and water surface elevations in the affected lake and in other lakes as releases are needed to meet downstream targets. For example, Tuttle Creek Lake loses a considerable amount of its multipurpose pool capacity in the future, and releases from Milford Lake will be needed to meet water supply and water quality targets. Future sedimentation in reservoirs can affect future reservoir depths, boating accessibility, and other conditions that would affect recreation. In severe situations, boat ramps and marinas may be silted in and may not be accessed for water-based recreation. This may especially be the case during drought and relatively drier conditions

when lower lake elevations combined with shallower lakes render boat ramps inaccessible, as well as decrease nutrients and fish habitat in the reservoirs, decreasing recreation opportunities.

H&H data, notably reservoir elevations and river flows, are available for most of the USACE reservoirs, Waconda Lake, and the Kansas River mainstem. The future H&H projections (FWOP) evaluated four timeframes, both with and without navigation releases: 2024 (Year 0 – Year when the Watershed Study is complete), 2049 (Year 25), 2074 (Year 50), and 2124 (Year 100). Water surface elevation models were developed to link the hydrology and hydraulic data and critical lake elevations and river flows for recreation to estimate potential changes in visitation, consumer surplus values, and jobs and income in local communities.

The USACE's Hydrologic Engineering Center Reservoir Simulation (HEC-ResSim)models simulated daily reservoir water surface elevations, storage, and releases (flows) for the period or record from 1919 to 2020 for existing conditions. The HEC-ResSim also modeled eight FWOP scenarios modeled over the period between 2023 and 2124 (see Appendix B). The eight FWOP scenarios include four with navigation releases at the four timeframes used for the sediment assessment (2024, 2049, 2074, and 2124) and four without navigation releases at the timeframes used for the sediment assessment (2024, 2049, 2074, and 2124). These four timeframes represent points in time in the future and the expected reservoir sedimentation at those years expanded out over the period of analysis (see Appendix D). These FWOP scenarios consider reservoir releases to meet target flows, water use assumptions, future water withdrawals, projected inflows, and sedimentation accumulation within the reservoirs in the future.

For the lakes that would be impacted by future sediment deposition (Tuttle Creek, Perry, Kanopolis, Harlan County, and Waconda lakes), drought and relatively drier conditions would likely result in shallower pools during lower water levels. Because both water surface elevations and sediment deposition and depths are available for these lakes, the evaluation considers both sediment depths and water surface elevations in the impacts to visitation at these lakes. H&H data on reservoir elevations is available for Tuttle Creek, Clinton, Perry, Kanopolis, Milford, Wilson, and Waconda reservoirs, and water surface elevation models were developed for these reservoirs and the Kansas River mainstem. Recreation on the Kansas River mainstem is evaluated through critical river flows needed to support boating during the spring, summer, and fall months with the USACE's Hydrologic Engineering Center's River Analysis System (HEC-RAS) river flow data. Elevation thresholds were provided by the Kansas River boating organization representatives. Recreation on the Kansas River is not notably affected by sediment (Buehler, 2020).

2.2.2. Visitation

The quantitative recreation evaluation and models use 2018 as a base year for visitation. When the models were developed 2018 was the most recent year of visitation data available for an average water year. While 2019 visitation data was available, the region experienced a considerable flood during that timeframe and the visitation data was not a good representation of typical conditions. The Corps Visitation Estimation and Reporting system (VERS) visitation data was used for the USACE reservoirs, and the KDWP state park visitation estimates for the BOR reservoirs. For state parks that are within the USACE projects, we replace the USACE VERS estimates and used the state park visitation estimates. Information from an electronic permit system iSportsman is in place in Kansas that requires hunters to electronically register for 24 of the wildlife areas in Kansas. iSportsman data was used to estimate hunting visitation and was adjusted to reflect hunting visits for people that do not necessarily register with the system. Wildlife viewing also occurs in the wildlife areas; we used the United States Fish and Wildlife Service (USFWS) 2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation report, which indicates that wildlife viewing visits across the state is generally about 20 percent of the hunting

visits. This percentage was applied to the hunting visit estimates to obtain an estimate of wildlife viewing visitation at each reservoir.

In order to understand visitor trends over time to assess whether visitation would increase in the future, visitation data compiled for state parks from 2003 to 2022 (excluding 2019-2021 due to flooding and COVID conditions) was evaluated (VERS data is not available prior to 2014For most of the reservoirs, there were stable or decreases in visitation trends at state parks over time). State parks at Wilson, Tuttle Creek, and Cedar Bluff reservoirs experienced decreasing visitation. It is likely that decreasing visitation at these reservoirs is tied to previous and low inflows and water surface elevations, rendering boat ramps inaccessible. For this reason, we assume that the recreation modeling is capturing these decreasing visitation trends in the future.

Visitation at the state parks at Waconda and Kanopolis reservoirs shows increases of 24% and 11%, respectively, over the 16-year time period, with implications to consumer surplus and regional economic effects. See Section 5.2 and Section 4.1 for additional discussion of future visitation at Waconda and Kanopolis reservoirs.

For the lakes impacted by sediment in the future, the reservoir depth maps were used to identify the recreation areas and infrastructure (i.e., marinas and boat ramps) adjacent to the lake that would no longer be accessible for water-based visitors. 2018 visitation estimates were used at impacted recreation areas to identify water- and shore-based visitation potentially affected by sediment deposition. Activity distributions from VERS were used to identify shore- and water-based visitors at the recreation areas at each lake; these two groups of visitors (water- and shore-based visitors) are affected differently by changes in lake-elevations. Boating, angling, water contact, and other activities were assumed to be "water-based activities," while the remaining activities were assumed to be shore-based. USACE lake staff and KDWP public lands, recreation, and fisheries staff provided input for these assumptions.

An important piece of the evaluation using the quantitative models for recreation is understanding how reservoir elevations and river flows impact recreation at the reservoir and in river reaches. USACE operations project managers, additional reservoir staff, and KDWP staff were consulted to obtain critical lake elevations important to recreation on the six USACE reservoirs and the one USBR reservoir modeled. Additionally, boating organizations on the Kansas River provided information on river flows important to boating on the Kansas River mainstem.

These critical elevations are provided for each reservoir assessed and the Kansas River mainstem in the following sections. The models assume that if the reservoir elevations fall within various key thresholds identified by USACE and KDWP reservoir staff, water-based visitation and shore-based visitation would be impacted.

Not all recreation areas are likely to be directly impacted by changes in lake elevations. Based on a review of the project and lake maps, a judgment was made regarding whether the recreation areas at each of the reservoirs would be affected by changes in lake elevations. Often, these are recreation areas or state parks located on or adjacent to the lake (not below the dam) and generally include those with boat ramps and/or marinas. Wildlife areas are assumed to not be affected by level elevations because most of the uses are upstream of the lakes and not affected by lake elevations. Dispersed recreation was assumed to be impacted by lake elevations, as some of dispersed recreation includes boating.

The water surface elevations recreation models assume that a percent of water-based visitors and shorebased visitors would be impacted at recreation areas potentially affected by lake elevations. In reality, some of the visitation may shift to other areas within the lake, shift from water-based activities to shorebased activities near a lake, or move to another lake within the area. The modeling results will focus on the dramatic or extreme changes in water surface elevations in the future compared to current conditions (i.e., usually occurring during drought or flooding events), where there may be limited options for visitors at the affected lake.

2.2.3. Consumer Surplus Values

The approach to estimating the value of recreation is to use consumer surplus values or willingness to pay, which is the value a person realizes from engaging in outdoor recreation above and beyond the expenditures incurred for the visit. Consumer surplus values are generally higher with more specialized recreational activities; that is, fishing and hunting activities would have a higher unit day value (UDV) than site-seeing activities. The UDV approach is USACE-certified, providing estimates of the value of recreation through recreation-area specific ratings for criteria at each recreation site. The UDV method of estimating willingness to pay relies on expert and informed opinion to assign relative values to recreation days based on the quality of recreational opportunities supported by individual recreation areas. The USACE Economic Guidance Memorandum (EGM), EGM 22-03 (Unit Day Values for Recreation, Fiscal Year 2022), provides guidelines for assigning points on a 100-point scale based on five recreation areas based on these five criteria. Point ratings are then converted into a monetary value based on values published in EGM 20-03 for each of the four categories of recreation (general recreation, general hunting and fishing, and other specialized activities).

The point ratings for each USACE recreation area were obtained from the USACE Recreation Budget Evaluation System (Rec-BEST) database for 2018 to 2020. The UDV points were weighted by visitation over a two-year period (2018 and 2020) to estimate the lake-wide UDV for the four categories; 2019 was omitted due to the 2019 flood. The USBR lake UDV points were estimated based on an evaluation of the five UDV criteria. Information from lake managers and staff was used to estimate the prevalence of specialized visitation (i.e., ATV, specialized fishing, equestrian use, and others) at each of the lakes that would fall into the relatively higher-valued categories. The VERS activity distributions were used to estimate visitation associated with the general and hunting and fishing categories.

2.2.4. Regional Economic Benefits

The USACE Regional Economic System 2 (RECONS), developed by the Institute for Water Resources (IWR), estimates the regional economic impacts of USACE investment spending and project activities in the USACE's business lines. RECONS is a Corps-certified model that estimates economic output, jobs, earnings, and value added associated with visitation at Corps projects. Labor income, value added, and economic output are provided in 2022 dollars. RECONS uses Economic Impact Analysis for Planning's (IMPLAN©'s) software and data system to estimate the economic effects of visitation, including direct effects (visitor spending) and multiplier effects (indirect and induced effects). The RECONS model, by default, estimates the economic impacts of visitor spending for three study areas: local, state, and the nation. The local study area is specified by default based on USACE project areas. The local study area usually includes the counties within and surrounding a project's boundary, including counties within 30 to 50 miles of the project area. The state study area includes the state or states in which the local study area is located.

There are six visitor segments in the RECONS model:

- 1. Local day use visitor and non-boater
- 2. Local day use visitor and boater
- 3. Overnight camper or other overnight project visitor within project and boater

- 4. Overnight camper or other overnight project visitor within project and non-boater
- 5. Non-local visitor (coming from more than 50 miles from project to stay in local communities) and boater
- 6. Non-local visitor (coming from more than 50 miles from project to stay in local communities) and non-boater

The USACE VERS activity distributions were used to identify visits at the reservoirs associated with the above visitor segments; for BOR reservoirs, lake staff provided input on these visitor categories.

2.3. Assumptions, Considerations, and Uncertainty

There is uncertainty associated with the assumptions described in the following sections. Where possible, the project team has obtained information from experts or lake staff to attempt to support these assumptions. However, there is uncertainty regarding a number of the visitation parameters, including the response of visitors to changes in water surface elevations (critical lake elevations) and sediment conditions and their ability to adapt overtime.

The visitation and economic evaluations use data from the hydrologic and hydraulic (H&H) and sediment modeling of the river and reservoir system (Appendix B, Appendix C and Appendix D). Recreation models that estimate changes in visitation and economic impacts from changes in water surface elevations rely on critical lake elevation thresholds for recreation that were obtained from USACE lake staff and KDWP public lands, recreation, and fisheries staff on lake-wide impacts to visitation. It is assumed that if the reservoir elevations fall within various key thresholds identified by USACE or KDWP lake staff, visitation would be impacted, as described by the USACE lake and KDWP staff. In reality, some of the visitation may shift to other areas within the lake, shift from water-based activities to shore-based activities near a lake, or move to another lake within the area. The modeling results will focus on the dramatic or extreme changes in water surface elevations in the future compared to current conditions (i.e., during drought or flooding events), where there may be limited options for visitors at the affected lake.

Consistent with the unit day value (UDV) approach, the recreation water surface elevation modeling assumes that the lake wide UDV points and UDV per visitor day would remain the same under all water surface elevations. However, physical conditions at the lakes and reservoirs can affect the quality of recreational experience to the lake for water- and shore-based visitors, especially for visitors impacted by the severe sediment conditions, such as those at Tuttle Creek Lake in the future. As described in Section 2.2.3, the UDV measures the quality of the recreational experience and is based on lake staff ratings of five criteria, which are then aggregated into points (out of 100 total). UDV (consumer surplus) is estimated by natural resource managers at the lake, based on ratings of a number of criteria. In the FWOP, four of the five UDV criteria could potentially be impacted, including:

- Recreation experience
- Carrying capacity
- Accessibility
- Environmental quality

A potential change in the UDV and consumer surplus values are analyzed outside of the modeling effort with a sensitivity analysis in Section 3.4.1.4.1 (Consumer Surplus).

Severe impacts to recreation conditions at Tuttle Creek Reservoir under 2074 and 2124 FWOP scenario from sedimentation will likely contribute to lower quality of the recreation experience. Currently, the

visitation-weighted UDV at Tuttle Creek Lake is 44, which translates to a general UDV of \$8.89 and a general hunting and fishing UDV of \$9.91 (FY2022 dollars).

The considerable sedimentation impacts at Tuttle Creek Lake could result in notable decreases in the UDV points ratings for recreation experience, carrying capacity, accessibility, and environmental quality. With a decrease of 25 to 50% of the UDV points, the UDV points would be 33 and 22, respectively, and the UDV would change from \$8.98 (general) and \$9.91 (general hunting and fishing) to:

- General: \$6.08 (UDV points of 22) to \$7.26 (UDV points of 33)
- General hunting and fishing: \$8.05 (UDV points of 22) to \$8.98 (UDV points of 33)

Based on these changes in the UDV, impacts to consumer surplus under FWOP 2074 and 2124 could be less than estimated above. For example, in 2074 and 2124, there would be 367,000 recreation visitor days potentially impacted with an associated impact of \$3.3 million in consumer surplus (both land- and shore-based visitors); those visitors with a relatively lower UDV would receive between \$2.3 to \$2.7 million in consumer surplus value, reducing impacts under future conditions because of the relatively lower quality of recreational experience at Tuttle Creek Lake in the future.

3.0. Kansas Regional Planning Area

The Kansas Regional Planning Area is composed of 21 different counties and encompasses 9,114 square miles in Northeast Kansas. Four USACE reservoirs, Clinton, Milford, Perry, and Tuttle Creek along with the Kansas River mainstem are in the Kansas Regional Planning Area. Reservoirs and the Kansas River mainstem located in the Kansas Regional Planning area are shown in Figure 1.



Figure 1: The Kansas Regional Planning Area

3.1. Clinton Reservoir

Clinton Lake is located approximately 1 mile west of Lawrence, Kansas on the Wakarusa River and stretches into both Douglas and Shawnee counties (see Figure 2). The reservoir was constructed by USACE for the purposes of flood control, municipal and industrial water supply, recreation and to maintain stream flow on the Wakarusa and Kansas Rivers.



Figure 2. Clinton Reservoir Recreation Areas

3.1.1. Existing Conditions

3.1.1.1. Recreation Facilities and Visitation

Clinton Reservoir includes six parks, three managed by the USACE, two managed by KDWP, and one managed by the City of Lawrence. Below highlights the numerous recreational opportunities available at Clinton Reservoir:

- Boat Ramps
- Picnic Areas
- Hiking Trails
- Bike Trails
- Campsites
- Disc Golf Courses

- Golf Course
- Cross Country Ski Trail
- Softball Complex
- Equestrian Trail
- Swimming Beach

According to combined USACE and KDWP data, total visitation in 2018 was 1,801,100 (USACE and KDWP 2018a). In 2018, the most popular areas at the reservoir were the City of Lawrence outlet park, accounting for approximately 44% of total visitation, followed by Clinton State Park (25%), and Bloomington East Park (12%). Sightseeing activities account for the largest share of visitation activities at Clinton Reservoir at 21%, followed by hiking/jogging/walking at 16%, and picnickers at approximately 14%. Water based activities and camping account for 11% and 8% of total visitation activities at Clinton Reservoir, respectively. Special events accounted for 5% of visitation in 2018 (USACE and KDWP 2018a). According to 2018 iSportsman data (KDWP 2021), there were 4,269 hunting visits within wildlife areas managed by KDWP associated with the reservoir, comprising 0.2% of total activities, and 854 wildlife viewing visits (KDWP iSportsman data). In 2019, there were 48 special events at Clinton Reservoir, including fishing tournaments and derbies, bike races, hikes, and more (Clinton Lake Meeting – Flannagar; December 2020).

Rockhaven is a specialized campground for equestrian users. It is also the main trailhead for 60 miles of horse and hiking trails along the south side of Clinton Reservoir. Users come from Kansas and the surrounding states to utilize the campground and trails. Woodridge Park is a 900-acre primitive "backpacking" area. Users can camp in a primitive setting throughout the 900-acre park.

3.1.1.2. Sport Fisheries

This section provides a summary of sport fishing at Clinton Reservoir. Additional information is provided in the Reservoir Fisheries Technical Report (see Appendix E). Fish species that occur at Clinton Reservoir include 14 sportfish species like black crappie, blue catfish, and wiper and 13 non-sport fish species like creek chub, freshwater drum, and sand shiner. The top four most preferred species of fish by anglers includes crappie, catfish species, and walleye.

Factors that affect the fishery at Clinton Reservoir include general limnology, water quality, water level fluctuations, sedimentation, vegetated fishery habitats, and invasive and exotic species. Many limnological characteristics of Clinton Reservoir are resultant from its large watershed, large surface area (7000 acres), and relatively shallow depths (mean depth = 17.0 ft, maximum depth = 36.1 ft). The reservoirs large watershed contains a variety of land use practices including grasslands (61.7%), forest (14.9%), agriculture (12%), and urban (6.2%). Sedimentation can affect the natural resources in the lake. Suspended sediments carry nutrients and metals which accelerates eutrophication and can limit fishery production for native and game fish species. As the lake fills with sediments from upstream it reduces the water volume available to fish. In addition, the sediment covers the habitat that many fish species use for foraging or spawning. Furthermore, the large mudflats created in the upper reaches of the lake serves as a disconnect between the lake and the upstream river system that some fish species use for annual migrations or spawning runs. High turbidity from suspended sediments also has impacts on the ability for sight feeders to be able to adequately capture food. During periods of extended high turbidity, the sampling data records lower abundance of forage species and lower body condition of sportfish.

The objective of fisheries management at Clinton Reservoir is to optimize the quality and diversity of angling opportunities. Specific management activities include tailoring fish harvest regulations to changes in sportfish population trends, stocking fish to enhance population abundance as needed, construction of fish attractors to enhance angling opportunities, and other activities for maintaining/improving angling access.

The sportfish community in Clinton Reservoir is routinely surveyed using a variety of different techniques for targeting specific species. Typically, all sportfish are measured for total length, weight, and total catch. These data are used to calculate relative abundance, size structure, body condition, and year

class strength. These data are used to inform species specific management strategies (i.e., harvest regulations, stocking regime). In Kansas, as is the case in many other states, harvest of various sportfish species at waters open to public angling is regulated by length and creel limits. Other specific management activities include stocking fish to enhance population abundance as needed, construction of fish attractors to enhance angling opportunities, and other activities for maintaining/improving angling access. Historically, several sportfish species have been stocked in Clinton Reservoir to maintain sportfish populations or create new angling opportunities. Maintenance stockings have occurred for Percids (walleye, sauger, saugeye), largemouth bass, and channel catfish. Introductory stockings have occurred for blue catfish and hybrid striped bass. Appendix E contains further details related to these mitigation actions and information about reservoir sportfish species and factors affecting their abundance and distribution.

3.1.1.3. Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

Like other lakes in the region, the 2019 flood impacted recreation at Clinton Reservoir. Due to the spring flood event, the lake was above normal pool for over 60 days, with a max crest of 21 feet above top of multi-purpose pool (USACE 2020). In USACE areas, three miles of roads, parking, and trails were submerged and required restoration and repair.

At the USACE areas and Clinton State Park, there were considerable damages to recreation facilities from the 2019 flood. During a meeting in December 2020, USACE and KDWP Clinton Reservoir staff described the impacts of the 2019 flood. There were numerous closures, including the entire beach area and campgrounds. According to lake staff, there were more impacts and closures at the USACE sites leading to higher visitor use at the state park. Additionally, people were coming to Clinton Reservoir to observe some of the high water areas which contributed to a 4% increase in overall visitation in 2019 (1,880,616 visitors) compared to 2018 (1,801,100 visitors) (USACE and State Park data).

Drought events, especially during the late 1980s, 1990s, early to mid-2000s, and 2012, have affected recreation at Clinton Reservoir (USGS, Kansas Droughts, need date) (NOAA, 2020). However, Clinton Reservoir staff indicated that the effect of these modest drought periods on recreation was not a particularly large effect. Fishing and boating access was limited, but most day use including camping continued. During low water/drought conditions when the pool drops more than three feet below the multi-purpose pool (872 feet), submerged rocks and obstacles start to impact boating at the lake. Below 865 feet, no boating and water-based access can occur, and exposed shorelines, rocks, and steep banks provide obstacles and reduce the aesthetic qualities for visitors. During low water/drought conditions the wildlife areas are impacted because there is less water for the adjacent wetlands. This impacts duck and waterfowl habitat and hunters may not choose to come if ducks and waterfowl are low in numbers.

There are no current issues with sediment affecting recreational opportunities at Clinton Reservoir. Clinton Reservoir has not experienced recreation impacts from harmful algal blooms (HABs).

3.1.1.1. Critical Lake Elevations for Recreation

Lake elevations are an important factor for water- and shore-based recreation at Clinton Reservoir. Working with the USACE lake staff and KDWP fisheries experts, critical lake elevations for recreation were identified at Clinton Reservoir as well as the corresponding impacts to visitation (Tables 2 and 3). These lake elevations are used in the recreation modeling effort to assess the impacts to visitation and economic benefits under FWOP conditions. Other important water surface elevations for the reservoirs are part of the lake level management plans, which specify lake elevations to support fish and wildlife. It is important to note that water surface elevation and depth of water are not equivalent. For example, the water surface elevation may rise five feet above the multi-purpose pool, but if 10 feet of sediment were to accrue at the bottom of the lake, then the lake's depth would decrease five feet. This is not accounted for quantitatively in the model, but it is important to consider it qualitatively when assessing impacts of water surface elevation and depth to recreation, especially boating and fishing. Future reservoir sedimentation for Clinton Reservoir and any impacts to recreation are described in Section 3.1.2.

Table 2.	Critical	Lake	Elevations	for R	ecreation	at	Clinton ¹
	United	Lanc		101 14	corcation	uı	Omiton

Lake Elevations	<865 ft	865-872 ft	872-878; multi- purpose pool is 875.5 ft	878-882 ft	>882 ft	>884 ft
Visitation Impacts	No boating access, all boat ramps are unusable except Ramp 4. Camping is largely unaffected.	Boat ramps usable starting at elevation 865, Ramp 4 is useable above 866.	No Issues	Lower elevation campsites affected at this elevation, closing approximately 25% of campsites. Boat Ramp 4 unusable above 881.5.	Boating access is mostly not available, limiting fishing and recreational boating. The beach is not usable above elevation 879. Most boat ramps unavailable.	Trails at Clinton State Park begin to be affected by high water. Most campsites closed by high water.
Quality of Recreation Effects	Exposed shorelines with debris, rocks, steep banks. Underwater hazards exposed.	Boat ramps usable with caution, potential underwater hazards.	No Impacts	Some campsite impacts due to flooding.	Debris from flooding can become a safety concern.	

¹ The information in this table was developed with input from USACE and KDWP staff familiar with Clinton Reservoir. Lake Elevations are in NGVD 1929

Table 3. Percent of Reservoir Impacted by Critical Lake Elevation Thresholds

Lake Elevations	<865 ft	865-872 ft	872-878; multi- purpose pool is 875.5 ft	878-882 ft	>882 ft	>884 ft
Water-based Visitor Impacts	100%	25%	0%	5%	100%	100%
Shore-based Visitor Impacts	50%	0%	0%	25%	75%	100%

¹ The information in this table was developed with input from USACE and KDWP staff familiar with Clinton Reservoir. Lake Elevations are in NGVD 1929

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3.1.2. Future Without Project Condition

This section considers the impact of future conditions on recreation, including sediment, water surface elevations, water quality and fishery conditions. The first few sections describe how sediment and water surface elevations will change under the four FWOP scenarios, and how these changes will impact visitation and economic benefits. As navigation releases are not made from Clinton Reservoir the impacts of navigation releases are not considered for Clinton Reservoir. A qualitative evaluation of how changes in water quality will affect recreation in the future is provided in Sections 3.1.2.4.

3.1.2.1. Changes in Sediment and Water Surface Elevations

This section considers three precipitation conditions and their impacts on visitation and economic benefits under the FWOP scenarios, including typical precipitation periods, drought periods, and high water or flooding periods. To identify the drought and flood years, average annual elevations were analyzed across the period of record. Four years were chosen to evaluate flood conditions, with average annual elevations at Clinton Reservoir above 880 feet NGVD 29, while two years were chosen to evaluate drought conditions, with average annual elevations below 865 feet NGVD 29. See Table 2 and Table 3 for a description of impacts to recreation at different lake elevation thresholds.

Drought years include:

- 2059 (1955)
- 2060 (1956)

Flood years include:

- 2031 (1927)
- 2097 (1993)
- 2099 (1995)
- 2123 (2019)

Typical years include all other years.

3.1.2.1.1. Sediment Conditions

It is estimated that approximately 384 acre-feet of sediment accumulates on average annually in Clinton Reservoir. Sediment will continue to accumulate in Clinton Reservoir with an expected additional 7% loss of the multipurpose pool over the next 25 years (2049) and 12% loss over the next 50 years (2074) (Appendix D) bringing the capacity of the multipurpose pool to 96,669 acre-feet in 2074. Sedimentation has not generally impacted recreation at Clinton Reservoir.

While sediment will continue to accumulate (7% loss of the multipurpose pool over the next 25 years and 12% loss over the next 50 years) and the delta could extend, the size of the multipurpose pool and the lake's recreational opportunities are expected to be impacted very minimally. Figure 3, Figure 4, Figure 5, and Figure 6 show the depths of Clinton Reservoir at multi-purpose pool in 2024, 2049 (25 years), 2074 (50 years), and 2124 (100 years).

During typical precipitation conditions (at multi-purpose pool), the USACE sediment modeling indicates that with the exception of Coon Creek boat ramp on the north side of the reservoir, boat ramps at Clinton Reservoir would continue to provide boating access to the lake in under all FWOP scenarios.

During drought or flood conditions, the effects of sediment deposition in the future on recreational access remain generally the same as current conditions as the change in depths of the lake to an extent that would cause impacts are generally minor overall but there could be some localized impacts from sedimentation on shorelines or coves or in the delta area of Clinton Reservoir.

3.1.2.1.1. Water Surface Elevations

Clinton Reservoir does not lose significant storage over the 100-years of the FWOP. However, with each subsequent FWOP scenario, the average pool elevation increases as more sediment accumulates (Appendix B).

Clinton Reservoir modeling shows that median pool elevations tend to be near the top of multipurpose pool but slightly lower from July to March as water quality releases draw the reservoir down in the dry season. The pool elevation does not drop as far into the multipurpose pool in the later FWOP scenarios (FWOP 2074 and FWOP 2124) likely because of reduced evaporation from smaller pool areas as evaporation is a large driver of pool elevation at Clinton Reservoir. There are also small increased frequencies of higher pool elevations in the flood control pool under FWOP scenarios compared to FWOP 2024. Additional information is provided in Appendix B.

FWOP Scenario	Average Water Surface Elevations (feet)	Change in Average Water Surface Elevations from 2024 (feet)
2024	874.65	
2049	874.69	0.04
2074	874.79	0.14
2124	874.88	0.23

Table 1	Average	\A/atar	Curfooo	Elevetione	of Clinton	Decement
Table 4.	Average	water	Surface	Elevations	at Clinton	Reservoir

Note: The top of the multi-purpose pool is 875.5 feet. Elevations are in NGVD 1929.

Represents average across the period of record.

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Figure 3. Clinton Reservoir Baseline Depths - 2024



Figure 4. Clinton Reservoir Future Depths with Projected Sedimentation – 2049 (25 Years)



Figure 5. Clinton Reservoir Future Depths with Projected Sedimentation – 2074 (50 Years)



Figure 6. Clinton Reservoir Future Depths with Projected Sedimentation – 2124 (100 Years)

There are two notable drought years over the 100-period of analysis: 2059 (translates to past year of 1955), and 2060 (translates to past year of 1956). There are four notable high water or flood years over the 100-year period of analysis: 2031 (translates to past year of 1927), 2097 (translates to past year of 1993), 2099 (translates to past year of 1995), and 2123 (translates to past year of 2019).

Under both flooding and drought conditions, on average, pools levels are higher in FWOP 2049, 2074, and 2124 conditions than experienced under FWOP 2024 conditions, with the exception of flooding under the FWOP 2074 (Table 5). During drought conditions, on average in 2059 and 2060 pool levels in 25 years (2049) are approximately less than 0.2 feet higher, while in 50 and 100 years, pool levels are approximately 0.5 foot higher on average in 50 years and slightly over a foot higher under 2124 FWOP conditions.

FWOP Scenario	Change in Average Water Surface Elevations from 2024 During Drought Years (feet)	Change in Average Water Surface Elevations from 2024 During Flood Years (feet)
2049	0.16	0.64
2074	0.49	-0.12
2124	1.09	0.17

Table 5. Average	Annual Water	Surface Elevation	s Durina Drou	oht and Flood Years
Tuble of Atterage	/ liniaal ffator		o Baring Broc	gint and i lood i ouro

Note: The top of the multi-purpose pool is 875.5 feet NGVD 29

During the 2059 and 2060 drought years, under the FWOP 2024 scenarios, the pool is between 861 and 864 feet (from one to four feet lower than multipurpose pool).

Drought conditions, similar to those experienced in the mid-1950s, result in relatively lower water surface elevations for almost two years between 2059 and 2060, which could result in major implications for recreation with impacts to visitation and revenues over a prolonged period. See Section 3.1.2.2.2 for more detail on drought impacts to recreation.

During drought or flood conditions, water surface elevations do not reduce the depths of the lake to an extent that would cause impacts (see description on water surface elevations).

Under three notable high water or flood years over the 100-year period of analysis, as shown in Table 5, on average, water surface elevations are higher on average under the FWOP 2049 and 2124 conditions and slightly higher under the FWOP 2074 conditions compared to FWOP 2024. During peak water surface elevations in these years, the difference among the water surface elevations under all FWOP scenarios is minimal (-0.17 to +0.64 feet).

3.1.2.2. Changes in Visitation

This section describes how changes and lake elevations can potentially impact visitation at Clinton Reservoir. Impacts from sediment are not discussed as Clinton Reservoir does not loose substantial storage over the 100 years of the FWOP. In the following sections the potential impacts to visitation are described compared to all visitation during typical conditions at the lake-elevation affected recreation areas under the baseline year, 2018. In 2018, 910,000 people visited recreation areas that are potentially impacted by lake elevations, which includes dispersed recreation. The study team also compared the impacted visitation to 2018 baseline visitation at all locations at Clinton Reservoir. In 2018, visitation across Clinton Reservoir was estimated to be 1,801,100.

3.1.2.2.1. Typical Precipitation Conditions

Drought and flood conditions are the main driver of recreation impacts across the reservoir, although HABs can exacerbate these impacts to recreation further decreasing access and quality of recreation at the

reservoir. Under typical precipitation visitation under the 100 years of the FWOP is assumed to remain similar to past visitation.

3.1.2.2.2. Drought Conditions

During drought conditions, consistent with the historic drought of the mid-1950s, water surface elevations are moderately lower than the top of multipurpose pool across all FWOP scenarios (from one to four feet lower than multipurpose pool during this period) and below thresholds important for recreation. In drought conditions, consistent with mid-1950s water conditions, all water-based access at recreation areas at the lake would be impacted under all FWOP scenarios with no boating access and exposed shorelines with debris, rocks, steep banks, and under hazards exposed. This would have multi-year impacts as the fishery could also be impacted, recreation infrastructure (e.g., boat ramps) may require repairs and modifications, visitation would be impacted, and revenue sources to maintain the lakes would decrease.

Modeling of water surface elevations and critical lake elevations for recreation in the FWOP 2024 scenario show that in 2060 (modeled after 1956 drought conditions), visitation at the recreation areas that could potentially be impacted by changes in lake elevations would be 320,500, a reduction of approximately 589,500 visitors from 2018 baseline conditions at lake-elevation affected recreation areas (Table 10).

3.1.2.2.3. Flood Conditions

Within the 100-year period of analysis, considerable flood events would occur under the FWOP in 2031 (modeled after 1927 conditions), 2097 (1993), 2099 (1995), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation in FWOP 2024, FWOP 2049, FWOP 2074, and FWOP 2124 conditions show considerable impacts to visitation at the recreation areas adjacent to the lake in these years (Tables 6, 7, 8, and 9). A reduction in visitation at recreation areas impacted by changes in water surface elevations at Clinton Reservoir in 2123, consistent with conditions experienced in 2019, indicates a potential visitation decrease of 76% compared to baseline conditions at Clinton Reservoir (2018).

Table 6 below shows how flood conditions under the 2024 FWOP affect recreation in areas affected by changes in lake elevations by comparing visitation at those areas in modeled "flood years" (2031, 2097, 2099, and 2123) to baseline conditions (2018).

Flooding Years	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Percent Decrease in Visitation at Lake-Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018) at All Recreation Areas
Visitation under Baseline Conditions (2018)	910,000	-	-	1,801,000
2031	482,000	-428,000	-47%	-27%
2097	504,000	-406,000	-45%	-23%
2099	483,000	-427,000	-47%	-24%
2123	216,000	-694,000	-76%	-39%

Fable 6. Annual Changes in Visitati	on Associated with Modeled	Flood Events, FWOP 2024
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With flooding conditions, potentially more shore-based visitors could be impacted in the recreation areas around the lake as flooding can impact roads, trails and campgrounds with slightly higher reservoir

elevations under future conditions compared to the FWOP 2024 scenario. If all water- and shore-based visitors in the recreation areas adjacent to the lake are impacted during flooding conditions, 910,000 visitors would be affected, representing 51% of visitation under baseline conditions at Clinton Reservoir (2018).

Tables 7, 8, and 9 below show how flood conditions under the 2049, 2074, and 2124 FWOP scenarios affect recreation in areas affected by changes in lake elevations by comparing visitation at those areas in modeled "flood years" (2031, 2097, 2099, and 2123) to baseline conditions (2018).

Flooding Years	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Percent Decrease in Visitation at Lake-Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018) at All Recreation Areas
Visitation under Baseline Conditions (2018)	910,000	-	-	1,801,000
2031	463,000	-447,000	-49%	-25%
2097	509,000	-401,000	-44%	-22%
2099	363,000	-547,000	-60%	-30%
2123	214,000	-696,000	-76%	-39%

Tabla 7	Annual	Changes in	Visitation	Assasistad		Madalad	Flood	Evente		2040
rapie 7.	Annual	Changes in	visitation	Associated	with	wodeled	FIOOU	Evenus,	FVVOP	2049

Table 8. Annual Changes in Visitation Associated with Modeled Flood Events, FWOP 2074

Flooding Years	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Percent Decrease in Visitation at Lake-Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018) at All Recreation Areas
Visitation under Baseline Conditions (2018)	910,000	-	-	1,801,000
2031	456,000	-454,000	-50%	-25%
2097	541,000	-369,000	-41%	-20%
2099	497,000	-413,000	-45%	-23%
2123	211,000	-699,000	-77%	-39%
Flooding Years	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Percent Decrease in Visitation at Lake-Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018) at All Recreation Areas
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Visitation under Baseline Conditions (2018)	910,000	-	-	1,801,000
2031	457,000	-453,000	-50%	-25%
2097	552,000	-358,000	-39%	-20%
2099	486,000	-424,000	-47%	-24%
2123	180,000	-730,000	-80%	-41%

Table 9. Annual Changes in Visitation Associated with Modeled Flood Events, FWOP 2124

Impacts on visitation under the three flood events could be high similar to past flood events. However, comparing water surface elevation impacts on visitation under the 2049, 2074, and 2124 FWOP scenarios during the four flood events, water surface elevations are minimally impacted (2049 - 1.9 foot increase-0.9 foot decrease; 2074 - 0.3 decrease to 0.4 foot increase; and 2124 - 0.4 feet decrease to 0.4 feet increase) compared to FWOP 2024. These minimal changes in water surface elevations under the three FWOP scenarios compared to FWOP 2024 during the four flood events has minimal effect on visitation compared to baseline visitation (2018) and shows some increase in impacts as shown in Tables 7, 8, and 9.

3.1.2.3. Changes in Economic Benefits

3.1.2.3.1. Consumer Surplus

Consumer surplus values are measured through the Corps' Unit Day Value (UDV) approach further described in Section 2.0. This section describes how changes and lake elevations and sediment conditions can potentially impact recreation consumer surplus values. Sediment deposition and relatively lower and higher water surface elevations have direct impacts on water-based visitors (boaters, swimmers, anglers) and indirect impacts to shore-based visitors for the recreation areas adjacent to the lake (termed lake-elevation affected recreation areas). In the following sections, the study team describes the potential impacts to consumer surplus values compared to all recreation values during typical conditions at the lake-elevation affected recreation areas under the baseline year, 2018.

Typical Precipitation Conditions

Visitation during baseline conditions at the recreation areas that are potentially impacted by lake elevations (including dispersed recreation) support an estimated \$9.8 million in consumer surplus value. The study team also compared the impacted consumer surplus values to baseline visitation and values (2018) at all locations at Clinton Reservoir. In 2018, visitation across Clinton Reservoir supported approximately \$19.3 million in consumer surplus values.¹

¹ Consumer surplus values are estimated with recreation visitor day and the Corps' UDV approach. In the modeling effort, visits were converted to recreation visitor days to apply the UDV using an estimate of average number of days per trip at the Kansas City District lakes to estimate consumer surplus. In this appendix, visitation is presented and described for consistency, and not recreation visitor days.

Impacts from sediment are not discussed as Clinton Reservoir does not lose significant storage over the 100 years of the FWOP.

Drought Conditions

The impacts to visitation during an extreme drought (below 865 feet NGVD 29) would impact all waterbased visitation at lake-elevation impacted recreation areas under all FWOP scenarios. Drought conditions can also affect shore-based visitors if the lake shore is further away from camping and picnic area, or if shallow pools pose unappealing features or conditions (e.g., odors, swampy areas, mosquitoes, etc.). With elevations below 865 feet NGVD 29, an estimated 50% of shore-based visitors could be impacted (see Table 2 and Table 3).

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled droughts years of 2059 and 2060 (modeled after 1955 and 1956 conditions), reduced visitation would translate to a potential loss in consumer surplus values during drought conditions of approximately \$5.6 to \$6.4 million annually (Table 10). These reductions in visitation in the recreation areas impacted by changes in lake elevations represent an annual decrease of 57% to 65% compared to 2018 baseline conditions.

Table 10. A	Annual Visitation and Consumer	[·] Surplus Changes	Associated with Dro	ought Events,
FWOP 202	4			

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake- Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus at Lake-Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus (2018)
Baseline condition (2018)	910,000	-	\$9.8 million	\$9.8 million	\$19.3 million
2059	389,300	-520,700	-\$5.6 million	-57%	-29%
2060	320,500	-589,500	-\$6.4 million	-65%	-33%

Consumer Surplus is expressed in FY22\$

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2049 conditions show that in modeled droughts years of 2059 (modeled after 1955 conditions) and 2060 (modeled after 1956 conditions), reduced visitation would translate to a potential loss in consumer surplus values during drought conditions of approximately \$5.1 to \$6.4 million annually (Table 11). These reductions in visitation in the recreation areas impacted by changes in lake elevations represent an annual decrease of 52% to 65% compared to 2018 baseline conditions.

Table 11. Annual Visitation and Consumer Surplus Changes Associated with Drought Events,FWOP 2049

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake- Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus at Lake-Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus (2018)
Baseline condition (2018)	910,000	-	\$9.8 million	\$9.8 million	\$19.3 million
2059	439,400	-470,600	-\$5.1 million	-52%	-26%
2060	320,500	-589,500	-\$6.4 million	-65%	-33%

Consumer Surplus is expressed in FY22\$

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2074 conditions show that in modeled droughts years of 2059 (modeled after 1955 conditions) and 2060 (modeled after 1956 conditions), reduced visitation would translate to a potential loss in consumer surplus values during drought conditions of approximately \$4.7 to \$6.4 million annually (Table 12). These reductions in visitation in the recreation areas impacted by changes in lake elevations represent an annual decrease of 48% to 65% compared to 2018 baseline conditions.

Table 12. Annual Visitation and Consumer Surplus Changes Associated with Drought Events,FWOP 2074

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake- Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus at Lake-Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus (2018)
Baseline condition (2018)	910,000	-	\$9.8 million	\$9.8 million	\$19.3 million
2059	472,500	-503,100	-\$4.7 million	-48%	-24%
2060	320,500	-589,500	-\$6.4 million	-65%	-33%

Consumer Surplus is expressed in FY22\$

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2124 conditions show that in modeled droughts years of 2059 (modeled after 1955 conditions) and 2060 (modeled after 1956 conditions), reduced visitation would translate to a potential loss in consumer surplus values during drought conditions of approximately \$3.3 to \$6.4 million annually (Table 13). These reductions in visitation in the recreation areas impacted by changes in lake elevations represent an annual decrease of 34% to 65% compared to 2018 baseline conditions.

Table 13. Annual Visitation and Consumer Surplus Changes Associated with Drought Events,FWOP 2124

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake- Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus at Lake-Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus (2018)
Baseline condition (2018)	910,000	-	\$9.8 million	\$9.8 million	\$19.3 million
2059	600,300	-309,700	-\$3.3 million	-34%	-17%
2060	320,500	-589,500	-\$6.4 million	-65%	-33%

Consumer Surplus is expressed in FY22\$

Flood Conditions

Within the 100-year period of analysis, considerable flood events would occur in 2031 (modeled after 1927 conditions), 2097 (1993), 2099 (1995), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss in consumer surplus values during flood conditions of between \$4.4 and \$7.5 million in consumer surplus values, representing a decrease between 23% and 39% of total consumer surplus at all locations at Clinton Reservoir under baseline conditions (Table 14 below). There could also be impacts to visitation at the recreation areas below the dam (e.g., Outlet Park) with potentially higher releases from the dam and localized flooding below the dam, although these impacts were not modeled.

Table 14. Annual Visitation and Consumer Surplus Changes Associated with Modeled FloodEvents, FWOP 2024

Flood Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake-Elevation Affected Areas	Percent Decrease in Visitation at Lake- Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018)
Baseline condition (2018)	910,000	-	\$9.8 million	\$9.8 million	\$19.3 million
2031	482,000	-428,000	-\$4.6 million	-47%	-24%
2097	504,000	-406,000	-\$4.4 million	-45%	-23%
2099	483,000	-427,000	-\$4.6 million	-47%	-24%
2123	216,000	-694,000	-\$7.5 million	-77%	-39%

Consumer Surplus is expressed in FY22\$

Under FWOP 2049, 2074, and 2124 conditions, water surface elevations are slightly higher on average compared to FWOP 2024 conditions during modeled years of 2031, 2097, 2099, and 2123 (Tables 15, 16, and 17). During peak water surface elevations in these years, the difference among the water surface

elevations under all FWOP scenarios is minimal with the highest reductions in consumer surplus in the FWOP 2124.

Table 15. Annual Visitation and Consumer Surplus Changes Associated with Modeled Flood	
Events, FWOP 2049	

Flood Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake-Elevation Affected Areas	Percent Decrease in Visitation at Lake- Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018)
Baseline condition (2018)	910,000	-	\$9.8 million	\$9.8 million	\$19.3 million
2031	463,000	-447,000	-\$4.3 million	-44%	-22%
2097	509,000	-401,000	-\$4.3 million	-44%	-22%
2099	363,000	-547,000	-\$5.9 million	-60%	-31%
2123	214,000	-696,000	-\$7.5 million	-77%	-39%

Consumer Surplus is expressed in FY22\$

Table 16. Annual Visitation and Consumer Surplus Changes Associated with Modeled FloodEvents, FWOP 2074

Flood Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake-Elevation Affected Areas	Percent Decrease in Visitation at Lake-Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018)
Baseline condition (2018)	910,000	-	\$9.8 million	\$9.8 million	\$19.3 million
2031	456,000	-454,000	-\$4.0 million	-41%	-21%
2097	541,000	-369,000	-\$4.0 million	-41%	-21%
2099	497,000	-413,000	-\$4.5 million	-46%	-23%
2123	211,000	-699,000	-\$7.5 million	-77%	-39%

Consumer Surplus is expressed in FY22\$

 Table 17. Annual Visitation and Consumer Surplus Changes Associated with Modeled Flood

 Events, FWOP 2124 (Consumer Surplus is expressed in FY22\$)

Flood Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake-Elevation Affected Areas	Percent Decrease in Visitation at Lake-Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018)
Baseline condition (2018)	910,000	-	\$9.8 million	\$9.8 million	\$19.3 million
2031	457,000	-453,000	-\$4.9 million	-50%	-25%
2097	552,000	-358,000	-\$3.9 million	-40%	-20%
2099	486,000	-424,000	-\$4.6 million	-47%	-24%
2123	180,000	-730,000	-\$7.9 million	-81%	-41%

3.1.2.3.2. Regional Economic Benefits

Regional economic impacts are estimated through the Corp's RECONS model and further described in Section 2. This section describes how changes and lake elevations and sediment conditions can potentially impact regional economic benefits (jobs and income) to adjacent communities. Visitors spend their money in local communities, providing regional economic benefits in these communities. Sediment deposition and relatively lower and higher water surface elevations have direct impacts on water-based visitors (boaters, swimmers, anglers) and indirect impacts to shore-based visitors for the recreation areas adjacent to the lake (termed lake-elevation affected recreation areas). In the following sections, the study team describes the potential impacts to regional economic benefits from reduced visitation compared to regional economic benefits supported under baseline conditions in 2018. Consistent with visitation in 2018, 1,801,100 visitors support 480 jobs and \$18.1 million in labor income in the local economy under baseline conditions. In the recreation areas potentially affected by changes in lake elevations under baseline conditions, 909,958 visitors support 255 jobs and \$9.7 million in labor income.

Typical Precipitation Conditions

Drought and flood conditions are the main driver of recreation impacts across the reservoir, although HABs can exacerbate these impacts to recreation further decreasing access and quality of recreation at the reservoir. Under typical precipitation visitation under the 100 years of the FWOP is assumed to remain similar to past visitation.

Impacts from sediment are not discussed as Clinton Reservoir does not lose significant storage over the 100 years of the FWOP.

Drought conditions

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled drought years of 2059 (translates to past year of 1955) and 2060 (modeled after 1956 conditions), reduced visitation would lead to a potential loss of 171 to 188 jobs and \$6.6 to \$7.3 million during drought conditions under 2024 FWOP compared to baseline conditions (Table 18). These reductions in economic benefits represent a 28% to 36% decrease in jobs from total jobs supported from all visitor spending at Clinton Reservoir under baseline conditions (480 annual jobs). Droughts can also have lasting impacts to tourism business depending on the timing of the recovery and

resiliency of the businesses, including the reservoir refilling, the re-establishment of the fishery, steps to mitigate losses in visitation, and the demand for recreation at the lake.

 Table 18. Annual Visitation and Changes in Regional Economic Benefits Associated with Drought

 Events, FWOP 2024

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Jobs at Lake- Elevation Affected Areas	Reduction in Labor Income at Lake- Elevation Affected Areas	Percent Decrease in Jobs and Income from Baseline Conditions
Baseline condition (2018)	910,000	-	255	\$9.7 million	480 jobs; \$18.1 million in labor income
2059	389,300	-520,700	-171	-\$6.6 million	-36%
2060	320,500	-589,500	-188	-\$7.3 million	-28%

Labor income is expressed in FY22\$

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2049 conditions show that in modeled drought years of 2059 (translates to past year of 1955) and 2060 (modeled after 1956 conditions), reduced visitation would lead to a potential loss of 158 to 188 jobs and \$6.1 to \$7.3 million during drought conditions under 2024 FWOP compared to baseline conditions (Table 19). These reductions in economic benefits represent a 34% to 40% decrease in jobs from total jobs supported from all visitor spending at Clinton Reservoir under baseline conditions (480 annual jobs).

Table 19. Annual Visitation and Changes in Regional Economic Benefits Associated with Drought Events, FWOP 2049

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Jobs at Lake- Elevation Affected Areas	Reduction in Labor Income at Lake- Elevation Affected Areas	Percent Decrease in Jobs and Income from Baseline Conditions
Baseline condition (2018)	910,000	-	255	\$9.7 million	480 jobs; \$18.1 million in labor income
2059	439,400	-470,600	-158	-\$6.1 million	-34%
2060	320,500	-589,500	-188	-\$7.3 million	-40%

Labor income is expressed in FY22\$

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2074 conditions show that in modeled drought years of 2059 (translates to past year of 1955) and 2060 (modeled after 1956 conditions), reduced visitation would lead to a potential loss of 147 to 188 jobs and \$5.7 to \$7.3 million during drought conditions under 2024 FWOP compared to baseline conditions (Table 20). These reductions in economic benefits represent a 32% to 40% decrease in jobs from total jobs supported from all visitor spending at Clinton Reservoir under baseline conditions (480 annual jobs).

Table 20. Annual Visitation and Changes in Regional Economic Benefits Associated with DroughtEvents, FWOP 2074

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Jobs at Lake- Elevation Affected Areas	Reduction in Labor Income at Lake- Elevation Affected Areas	Percent Decrease in Jobs and Income from Baseline Conditions
Baseline condition (2018)	910,000	-	255	\$9.7 million	480 jobs; \$18.1 million in labor income
2059	472,5	-503,100	-147	-\$5.7 million	-32%
2060	320,500	-589,500	-188	-\$7.3 million	-40%

Labor income is expressed in FY22\$

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2124 conditions show that in modeled drought years of 2059 (translates to past year of 1955) and 2060 (modeled after 1956 conditions), reduced visitation would lead to a potential loss of 104 to 188 jobs and \$4.1 to \$7.3 million during drought conditions under 2024 FWOP compared to baseline conditions (Table 21). These reductions in economic benefits represent a 23% to 40% decrease in jobs from total jobs supported from all visitor spending at Clinton Reservoir under baseline conditions (480 annual jobs).

Table 21. Annual Visitation and Changes in Regional Economic Benefits Associated with DroughtEvents, FWOP 2124

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake-Elevation Affected Areas from Baseline Visitation	Reduction in Jobs at Lake- Elevation Affected Areas	Reduction in Labor Income at Lake-Elevation Affected Areas	Percent Decrease in Jobs and Income from Baseline Conditions
Baseline condition (2018)	910,000	-	255	\$9.7 million	480 jobs; \$18.1 million in labor income
2059	600,300	-309,700	-104	-\$4.1 million	-23%
2060	320,500	-589,500	-188	-\$7.3 million	-40%

Labor income is expressed in FY22\$

Flood Conditions

Within the 100-year period of analysis, considerable flood events would occur in 2031 (modeled after 1927 conditions), 2097 (1993), 2099 (1995), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss of 119 to 204 jobs and \$4.5 to \$7.8 million in labor income, representing a decrease between 25% to 43% of total jobs supported by visitor spending at Clinton Reservoir under baseline conditions (Table 22). There could also be impacts to visitation at the recreation areas below the dam (e.g., Outlet Park) with potentially higher releases from the dam and localized flooding below the dam, although these impacts were not modeled.

Table 22. Annual Visitation and Changes in Regional Economic Benefits Associated with FloodEvents, FWOP 2024

Flood Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Jobs at Lake- Elevation Affected Areas	Reduction in Labor Income at Lake- Elevation Affected Areas	Percent Decrease in Jobs and Income from Baseline Conditions
Baseline condition (2018)	910,000	-	255	\$9.7 million	480 jobs; \$18.1 million in labor income
2031	482,000	-428,000	-127	-\$4.8 million	-27%
2097	504,000	-406,000	-119	-\$4.5 million	-25%
2099	483,000	-427,000	-133	-\$5.2 million	-29%
2123	216,000	-694,000	-204	-\$7.8 million	-43%

Labor income is expressed in FY22\$

Under the FWOP 2049, 2074, and 2124 scenarios, water surface elevations are slightly lower on average compared to FWOP 2024 conditions during modeled years of 2031, 2097, 2099, and 2123. During peak water surface elevations in these years, the difference among the water surface elevations under all FWOP scenarios is minimal and the impacts to the regional economic benefits (i.e., jobs and labor income) remain fairly consistent compared to FWOP 2024 for the modeled years of 2031, 2097, 2099, and 2123.

The results of the 100-year FWOP scenario (2124) are included in Table 23 as comparison. FWOP 2049 and 2074 have very similar results to the FWOP 2124.

Table 23. Annual Visitation and Changes in Regional Economic Benefits Associated with FloodEvents, FWOP 2124

Flood Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake-Elevation Affected Areas from Baseline Visitation	Reduction in Jobs at Lake- Elevation Affected Areas Reduction in Labor Income at Lake- Elevation Affected Areas		Percent Decrease in Jobs and Income from Baseline Conditions
Baseline condition (2018)	910,000	-	255	\$9.7 million	480 jobs; \$18.1 million in labor income
2031	457,000	-453,000	-136	-\$5.2 million	-29%
2097	552,000	-358,000	-103	-\$3.9 million	-22%
2099	486,000	-424,000	-132	-\$5.1 million	-28%
2123	180,000	-730,000	-214	-\$8.2 million	-45%

Labor income is expressed in FY22\$

Damages, Revenues, and Fees to States

Visitation to Clinton Reservoir contributes considerable revenue to the state to maintain parks. Revenue is collected through park entrance fees, camping fees, hunting and fishing license revenues, concessionaire fees. In 2018, the revenues associated with Clinton Reservoir were \$904,000, the highest lake revenue in

the state of Kansas.² At Clinton Reservoir in 2019, these revenues were \$829,000, a reduction of 8% from 2018 revenues due to reduced visitation from flooding events.

Hunting and fishing license sales are also important for the state, bringing in \$31.2 million in 2018 across the state, although this data is not available by lake. In general, these revenues vary over time and are typically proportional to visitation at the lakes. As described in this section, sediment deposition, droughts, and flooding conditions can have considerable impacts on this visitation and therefore revenue sources for the state. The evaluation indicates that drought conditions could result in an annual decrease of visitation up to 31% of baseline conditions (2018), while flooding impacts would have larger impact, impacting up to 39% of visitation under baseline conditions. These impacts would continue to occur overtime when droughts or flooding occur, with their occurrences becoming more frequent with climate change.

During these extreme events, the state and USACE often incur costs to repair damages, conduct small scale dredging, and other actions to repair or maintain infrastructure. Therefore, the state has less revenues coming in, with increased expenses, often impacting state coffers for years.

Estimated costs for repairs of recreational infrastructure associated with damage from the 2019 flood at USACE-managed recreation areas of Clinton Reservoir were \$355,000. The impacts at the KDWP state parks at Clinton Reservoir include damages to docks, fish cleaning stations, and campsites, as well as actions to remove debris are at \$264,000. These damages are likely to continue to occur in the future with extreme events.

3.1.2.4. Water Quality

Clinton Reservoir has not experienced recreation impacts from HABs. Deteriorating water quality could eventually lead to new occurrence of HABs in Clinton Reservoir with adverse impacts to visitors in the future. Impacts from HABs has been implicated in local economic impact from decrease in tourism/recreational visitation and are expected to continue in the future (Appendix G).

As described it is estimated that approximately 384 acre-feet of sediment accumulates on average annually at Clinton Reservoir. Sediment will continue to accumulate with an expected additional 7% loss of the multipurpose pool over the next 25 years and a 12% loss over the next 50 years (Appendix D). Reduced volume means less dilution and can equate to higher concentration of nutrients stored in the lake system. With the expected low amount of sediment expected to accumulate in Clinton Reservoir issues related to reduced dilution will not likely impact water quality or recreation at Clinton Reservoir.

Excess nutrients and fecal bacteria are the main impairments to Clinton Reservoir and the inflow TMDLs defined in the 303(d) list provided by KDHE. Cyanobacteria blooms occur at a low to moderate level and frequently result in taste and odor issues for drinking water supply. These impairments impact support of aquatic life, primary contact recreation, and all other designated used of affected areas with swim beaches frequently closed from bacteria. These impacts are expected to continue and potentially increase (see Appendix G) in the future causing reduced visitation and reduced visitor experience during periods when there are restrictions, warnings, or closure of favored recreation areas at Clinton Reservoir.

All reservoirs in the watershed, including Clinton Reservoir, will likely experience increasing effects of aging. Future water quality within watershed lakes is dependent on multiple influencing factors, some of which are challenging to predict and/or estimate. It can be assumed that continued, and increasing fertilizer use, will continue to influence the water quality of runoff, groundwater, streams, and lakes.

²These fees and revenues, generally paid by visitors to federal and state governments, are included in the estimate of economic output in described in Section 3.4.1.2.3.

Continued and enhanced water quality impairment may be expected at Clinton Reservoir. Consistent with existing conditions, storm events generating high run-off volumes will continue to transport the majority of sediment and nutrient loads to the reservoir. Based on an assessment of runoff/streamflow, sediment yield, and total nitrogen (TN) and total phosphorous (TP) yield under climate change runoff to Clinton Reservoir is expected to have a high increase in runoff/streamflow and TN yield leading to a medium increase in sediment yield and TP yield and a medium increase in TN yield that could lead to increased levels of eutrophication.

Water residence times were estimated for Clinton Reservoir (Appendix G). A reduction in residence time results in less time for nutrient and sediment constituents to settle within reservoirs and then passing them downstream. Reservoirs with higher sedimentation rates that are losing large portions of their multipurpose pool have the largest decreases in residence time expected in the future. Clinton Reservoir does not have a high sedimentation rate expected over the next 100 years and is estimated to have a reduction in residence time of 22% under the FWOP 2124. There will likely be a seasonality to these reductions in residence time with greater reductions during the wetter periods and increases during the drier periods.

3.1.2.5. Angling and Sport Fishery

Clinton Reservoir is filling in with sediment at the detriment of the fish and the anglers who pursue them as well as other interest groups that use the reservoir. Sedimentation of the reservoir reduces the storage capacity and area available to anglers, and fills in any unique, fish attracting bathymetric features (e.g., river channels). Decreased storage capacity will likely result in Clinton Reservoir being more responsive to heavy rains, exhibiting more drastic rises than were experienced when the river was impounded. The more drastic and frequent fluctuations will make the establishment and development of aquatic vegetation even more difficult. Further degradation of existing fish habitat will be countered with the installation of artificial fish habitat, but natural features are likely more appealing to fishes, and it is unknown if the rate of replacement can match the rate of degradation.

There is no reason to believe that use or visitation of Clinton Reservoir will be decreasing in the future. This reservoir is within close proximity to large population centers. The reservoir is already known for its exceptional crappie fishing and receives a good deal of traffic from tournament bass fishing, which is a growing sport. There is also the possibility that in the next ten years, Clinton Reservoir could develop a high-quality blue catfish fishery. If this population takes hold, it is likely to receive increased pressure from metropolitan catfishermen who would like a closer destination than Milford Reservoir.

While angler use may remain constant or increase, access to the reservoir may decrease. Continued siltation at the upper end of the reservoir may hinder angler access to that portion of the reservoir resulting in crowding at lower reservoir boat access areas. Similarly, more frequent, or more drastic water level fluctuations could result in most, if not all, boat ramps being closed to angler access. Without construction of new, higher elevation boat access points it is possible that anglers may not be able to access the reservoir during times of the year when rains are more frequent.

The loss of bathymetric features and silting in of natural fish attracting features will also negatively affect fish populations. Fish populations may begin to shift toward more riverine population structures which may not align with angler preference. Water level management will also continue to be crucial to sport fisheries and anglers. Available habitats and types, and successful sportfish reproduction and survival, can all be positively or negatively impacted by the timing of water releases and magnitudes thereof. High releases around spawning periods could be detrimental both on the local and statewide scale.

3.2. Milford Reservoir

Milford Reservoir is located on the Republican River in Geary County, Kansas (see Figure 7). It is on Highway 57, four miles northwest of Junction City, and 25 miles southeast of Clay Center. Milford Reservoir was created by USACE for the purposes of flood control, silt control, water quality, water supply, low flow supplementation, recreation, fish and wildlife, and support of navigation on the Missouri River.



Figure 7. Milford Lake Recreation Areas

3.2.1. Existing Conditions

3.2.1.1. Recreation Facilities and Visitation

Milford Reservoir offers a variety of recreational amenities, including 10 parks managed by KDWP or the USACE (Figure 7). A few city and county parks are also located adjacent to Milford Reservoir. Below highlights the numerous recreational opportunities available at Milford Reservoir:

- Boat Ramps
- Beaches
- Campsites
- Picnic Areas
- Hiking Trails

- Off-road Recreational Vehicle Trail
- Wildlife Areas
- Archery Hunting Areas
- Marinas

According to combined USACE and KDWP data, total visitation for 2018 was 1,579,700. In 2018, the state park, which includes Milford Nature Center and Clay County Park, accounted for 23% of total visitation at the lake recreation areas. Another popular destination at Milford Reservoir is Thunderbird Marina, accounting for 13% of the total 2018 visitation.

In terms of recreational activities, camping and water-contact activities together accounted for about 40% and 15% of all activities in 2018, respectively. Walking, hiking, and jogging accounted for a combined 5% of visitation while sightseeing and picnicking both accounted for a combined 19% of visitation (USACE VERS Data 2018). According to iSportsman data (KDWP), total hunting visits within the wildlife area managed by KDWP at Milford in 2018 were 10,880, accounting for 0.63% of all activities in 2018. Wildlife viewing visits totaled 2,176.

The lake holds several activities each year, including several fishing tournaments, bike and cardboard boat races, youth fishing days, and environmental education workshops for kids (Whitworth, 2020). Special events at Milford Reservoir account for approximately 2% of visitation. During a lake meeting on February 5, 2021, KDWP lake staff indicated that Milford Reservoir has annual fishing tournaments that are very popular, and sometimes bring in people from all over the country.

3.2.1.2. Sport Fisheries

This section provides a summary of sport fishing at Milford Reservoir. Additional information is provided in the Reservoir Fisheries Technical Report (see Appendix E). The objective of fisheries management at Milford Reservoir is to create quality fishing opportunities for anglers. Milford Reservoir provides a variety of species to appease many angler groups. Fish populations are managed through setting length limit and creel (also referred to as an angler survey) limit regulations, fish stockings to supplement existing populations, deploying artificial habitat, conducting creel surveys of anglers, and monitoring with sampling activities (Appendix E). Additionally, from February to May, the reservoir level is maintained at 1141.4 feet NGVD 29 to eradicate exposed zebra mussels and facilitate spawning areas for walleye.

Milford Reservoir is locally known as the "fishing capital of Kansas", and is a top destination for anglers, hunters, campers, etc. on a regular basis. Milford Reservoir is one the most popular fishing destinations in Kansas. Several species are sought after which draws anglers from all over Kansas and from out of state. Popularity at Milford Reservoir has drawn attention to many guide services and fishing tournament organizers from all over Kansas and the surrounding areas. Fishing tournaments happen frequently at Milford Reservoir and are hosted by local fishing clubs all the way up to national tournament trails. In recent years, groups such as I-70 bass club, Kansas Bass Nation, etc. hosted several bass tournaments at Milford Reservoir. Local catfish circuits (i.e., Catfish Chasers) also hold tournaments on Milford once or twice a year (Appendix E).

The data presented in Appendix E – Reservoir Fisheries highlights trends from the past five years excluding 2019 which was not sampled due to flooding. In 2018, an estimated 49,024 anglers fished Milford Reservoir. Anglers preferred "catfish" the most, second was wiper, third was blue catfish specifically, and fourth was "no preference", or "any" (Appendix E).

3.2.1.3. Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

Flood conditions at Milford Reservoir occurred throughout 2019. The flood of 2019 closed approximately 75% of all boat ramps, all USACE-managed campgrounds, and closed swimming beaches at USACE recreation areas. Due to the spring flood event, the reservoir was above multipurpose pool for over 110 days, with a water surface elevation 31 feet above the multipurpose pool (USACE 2020). The high water levels at Milford Reservoir damaged USACE and state recreation areas.

According to federal and state data, visitation in 2019 decreased by 20% in the summer (May-Aug), decreased by 21% in the fall (Sep-Dec), and increased in the winter (Jan-Apr) by 5%. Overall, total annual visitation between 2018 and 2019 decreased by 15% (USACE and KDWP 2018-2019). Rising water meant reservoir staff spent a substantial amount of time moving fishing dock cables and removing electrical breakers before the pedestals were flooded. While overall visitation decreased, during the 2019 flood, with just 2 boat ramps open, boating and fishing recreation remained stable. However, boaters experienced longer wait times at boat ramps with the reduction in ramps available (Whitworth 2020).

Drought conditions existed in late 2012 into 2013 (USGS, Kansas Droughts, 9/16/2020). The drought conditions reduced access to boat ramps, created issues for boaters due to exposed underwater hazards, and reduced fishing access (Whitworth, 2020). In a drought, lower lake elevations expose low water boat ramps, and people shift boat ramp use to deeper ramps. The USACE and out grantees often extend the shallower ramps further out to follow the water during drought conditions. If water level drops too low, people shift from fishing off of boats to fishing from the shore (Whitworth 2020).

High water increases duck habitat and spreads ducks out into areas where they normally would not go. Hunters must adjust to this but can still enjoy the same success as a normal lake level. High water pushes some deer further inland, again forcing hunters to adjust their tactics. Drought also impacts deer movement but creates quail/pheasant habitat from vegetation that grows on the now-exposed mudflats (Whitworth, 2020). Overall, some types of hunting may decrease while other types may increase, still offering hunters opportunities to recreate.

Sedimentation is an issue in the upper reaches of the lake, making the water shallower over time and increasing the need for the cleaning or dredging of boat ramps often causing these features to become temporarily inaccessible until maintenance is completed (Whitworth, 2020). The multipurpose pool at Milford Reservoir originally included 415,352 acre-feet of capacity (including the active pool and the inactive or dead pool). Approximately 11.8% of the multipurpose pool has been filled in with sediment leaving approximately 366,476 acre-ft of capacity (based on 2009 survey results) (Appendix D).

The impacts to visitation associated with HAB activity can depend on not only the presence of the HABs and their duration, but also on other variables or issues specific to each lake, including the prevalence of water-based visitors in the affected area, the locations of the HABs, and the availability of nearby parks or recreation areas and/or other lakes that recreators could use. HABs are prevalent at Milford Reservoir where highly variable algae blooms have led to HAB warnings five of seven years from 2011 to 2017, usually occurring between May and October (Table 24). Since Milford Reservoir is a large, zoned lake, some zones may have a HAB warning, while others are unaffected.

During the worst HAB year in 2016, Milford Lake experienced 19 weeks of HAB warning impacts (e.g., closed swim beaches and reduced boating activities) which included two weeks of "closure" or what is currently defined as "Public Health Hazard" conditions from extremely toxic HAB conditions that resulted in zones of the lake closed to all public access including boat ramps. In September of 2014, there were HAB hazards and closures in Zone C (upper part of the reservoir) from high algal cell count samples in the lake; warnings occurred at Milford Reservoir in 2014 in June, July, August, and September in all three zones in Milford Lake (see Figure 88 and Table 24). In years with no HAB warnings (2012 and 2013), limited inflows from drought low water years led to HAB minor blooms which never exceeded "watch" status.

Persistent warnings can decrease visitation at a lake, which can adversely affect economic activity in adjacent communities to the lakes. Although difficult to correlate warnings directly with decreased visitation, closures from HAB hazards seem to reduce visitation in affected months.



Figure 8. Milford Reservoir HAB Zones

Month	2014	2015	2016	2017	2018	2019	Average 2014-2019
Мау	235,030	143,708	128,645	141,478	198,744	149,857	166,244
June	166,653	224,166	210,611	202,595	212,771	142,913	193,258
July	164,898	194,607	256,801	178,047	191,642	150,912	189,485
Aug	138,162	157,698	259,500	134,562	152,988	166,019	168,155
Sept	111,150	161,201	169,383	142,166	125,557	128,378	139,639
Total Visitation (May-Sept)	815,893	881,380	1,024,940	798,848	881,702	738,079	856,807
%∆, May- September	-	15%	26%	-30%	14%	-15%	
Total Annual Visitation*	1,368,845	1,579,775	1,984,580	1,388,725	1,581,223	1,351,096	1,461,269

Table 24. Monthly Visitation at Milford Reservoir 2014-2019

*Includes hunting, dispersed use and wildlife area visitation

Although all three zones in Milford Reservoir have been affected by HAB warnings, Zone C has experienced more warnings than the other zones and is the only zone that has experienced closures (in 2014, 2015, and 2016) since 2014. Zone C encompasses Fort Riley Recreation area, Timber Creek Park, and Clay County Park, with Clay County Park having the vast majority of visitation. In 2014, 2015, and 2016, these three recreation areas supported less visitation overall in May through September than in 2017 and 2018 (2019 experienced flooding conditions that affected visitation at the lake).

Month	2014	2015	2016	2017	2018	2019	Average (2014-2019)
Мау	37,351	32,361	36,082	33,092	41,648	30,611	35,191
June	36,401	49,689	41,389	43,575	47,247	21,639	39,990
July	42,055	44,557	47,740	41,809	41,042	25,127	40,388
August	36,786	37,826	37,080	43,255	32,793	35,187	37,155
September	24,205	20,883	19,454	37,410	24,066	17,719	23,956
Visitation (May-Sept)	176,798	185,316	181,745	199,141	186,796	130,283	176,680
%Δ, May-September	-	4.80%	-1.90%	9.60%	-6.20%	-30.30%	-

 Table 25. Milford Reservoir Zone C Recreation Areas - Visitation

3.2.1.4. Critical Lake Elevations for Recreation

Lake elevations are an important factor for water- and shore-based recreation at Milford Reservoir. Working with the USACE lake staff and KDWP fisheries experts, critical lake elevations for recreation were identified at Milford Reservoir as well as the corresponding impacts to visitation (Table 26 and Table 27). These lake elevations are used in the recreation modeling effort to assess the impacts to visitation and economic benefits under FWOP conditions. Other important water surface elevations for the reservoirs are part of the lake level management plans, which specify lake elevations to support fish Page left intentionally blank.

Lake Elevations	<1,118 ft	1,118-1,130 ft	1,030-1141.4 ft	1,141.5-1148.5; multi-purpose pool is 1,144.4 ft	1,148.5-1,160 ft	>1,160 ft
Visitation Impacts	All boat ramps and marinas are closed below 1,118; shoreline and boat angling are compromised with reduced fishing opportunities.	Most boat ramps are not accessible; 11 of 13 of the boat ramps are not accessible. Milford State Park Marina and East Rolling Hills boat ramps remain accessible. Water-based visitation decreases.	Water access is maintained for some visitors; boating access is reduced at elevations below 1,137; overcrowding at usable boat ramps becomes a major issue.	Normal conditions	All boat ramps and marina are inaccessible above 1,148.5; shoreline access for anglers becomes difficult. Approximately half of campground sites are closed; water and electric are shut-off. Water-based visitation decreases.	Maneuver zones no longer accessible; additional camping areas, roads, and trails are inaccessible. Timberlane Cabins are inaccessible.
Quality of Recreation Effects	Extreme safety hazards for boaters and beach impacts. Reduced fishing success.	Overcrowding at usable boat ramps becomes a major issue. Shoreline fishing access is reduced. Safety hazards exist for boaters; silt and rocks on beach limits access and reduces aesthetics. Recreational "frustration" increases as boaters lose access and face ramp congestion.	Visitors start to complain about low water levels; safety hazards start to emerge for boaters.	No Impacts	Visitors start to complain about high water levels. Shoreline erosion begins to occur. Waterfowl hunting may expand into wetted areas, while areas for deer hunting may recede. Continued fishing success. Recreational "frustration" increases as boaters lose access and face ramp congestion.	Safety issues with debris with extreme high water; shoreline erosion.

Table 26. Critical Lake Elevations for Recreation at Milford Reservoir¹

¹ The information in this table was developed with input from USACE and KDWP staff familiar with Milford Reservoir. Lake Elevations are in NGVD 1929

Table 27. Percent of Reservoir Impacted by Critical Lake Elevation Thresholds¹

Lake Elevations	<1,118 ft	1,118-1,130 ft	1,030-1141.4 ft	1,141.5-1148.5; multi-purpose pool is 1,144.4 ft	1,148.5-1,160 ft	>1,160 ft
Water-based Visitor Impacts	100%	70%	40%	0%	100%	100%
Shore-based Visitor Impacts	75%	25%	25%	0%	50%	100%

¹ The information in this table was developed with input from USACE and KDWP staff familiar with Milford Reservoir. Lake Elevations are in NGVD 1929

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and wildlife. It is important to note that water surface elevation and depth of water are not equivalent. For example, the water surface elevation may rise five feet above the multi-purpose pool, but if 10 feet of sediment were to accrue at the bottom of the lake, then the lake's depth would decrease five feet. This is not accounted for quantitatively in the model, but it is important to consider it qualitatively when assessing impacts of water surface elevation and depth to recreation, especially boating and fishing. Future reservoir sedimentation for Milford Reservoir and any impacts to recreation are described in Section 3.2.1.

3.2.2. Future Without Project Conditions

This section considers the impact of future conditions on recreation, including sediment, water surface elevations, water quality and fishery conditions. The first few sections describe how sediment and water surface elevations will change under the four FWOP scenarios, and how these changes will impact visitation and economic benefits. The FWOP scenarios that include navigation releases are considered in Section 3.2.2.4. A qualitative evaluation of how changes in water quality and fishery conditions will affect recreation in the future is provided in Sections 3.2.2.5 and 3.2.2.6, respectively.

3.2.2.1. Changes in Sediment and Water Surface Elevations

This section considers three precipitation conditions and their impacts on visitation and economic benefits under the FWOP scenarios, including typical precipitation periods, drought periods, and high water or flooding periods. To identify the drought and flood years, average annual elevations were analyzed across the period of record. Three years were chosen to evaluate flood conditions, with average annual elevations at Milford Reservoir above 1,148 feet, while two years were chosen to evaluate drought conditions, with average annual elevations below 1,130 feet. See Tables 26 and 27 for a description of impacts to recreation at different lake elevation thresholds.

Drought years include:

- 2044 (1940)
- 2060 (1956)

Flood years include:

- 2055 (1951)
- 2097 (1993)
- 2123 (2019)

Typical years include all other years.

3.2.2.1.1. Sediment Conditions

It is estimated that approximately 468 acre-feet of sediment accumulates on average annually in Milford Reservoir. Sediment will continue to accumulate in Milford Reservoir with an expected additional 2.5 % loss of the multipurpose pool over the next 25 years (2049) and 4.0% loss over the next 50 years (2074) (Appendix D) bringing the capacity of the multipurpose pool to 349,881 acre-feet in 2074. Sedimentation has not generally impacted recreation at Milford Reservoir.

While sediment will continue to accumulate (2.5 % loss of the multipurpose pool over the next 25 years and 4.0% loss over the next 50 years) and the delta could extend, the size of the multipurpose pool and the lake's recreational opportunities are expected to be impacted very minimally, if at all. Figure **9**9, Figure 10, Figure 111, and Figure 122 show the depths of Milford Reservoir at multi-purpose pool in 2024, 2049 (25 years), 2074 (50 years), and 2124 (100 years).



Figure 9. Milford Reservoir Baseline Depths - 2024



Figure 10. Milford Reservoir Future Depths with Projected Sedimentation – 2049 (25 Years)



Figure 11. Milford Reservoir Future Depths with Projected Sedimentation – 2074 (50 Years)



Figure 12. Milford Reservoir Future Depths with Projected Sedimentation – 2124 (100 Years)

During typical precipitation conditions (at multi-purpose pool), the USACE sediment modeling indicates that boat ramps at Milford Reservoir would continue to provide boating access to the lake in under all FWOP scenarios.

During drought or flood conditions, the effects of sediment deposition in the future on recreational access remain generally the same.

3.2.2.1.2. Water Surface Elevations

Milford Reservoir does not lose significant storage over the 100-years of the FWOP. However, with each subsequent FWOP scenario, the average pool elevation decreases as Milford Reservoir is expected to release more to meet the water quality targets on the Kansas River mainstem (i.e., Desoto and Topeka) because of the reduced storage available in Tuttle Creek Reservoir to support water quality targets (Appendix B).

Milford Reservoir modeling shows small increases in frequency in the lower portions of the flood pool and deeper drops into the multipurpose pool as the storage diminishes due to sedimentation. Additional information is provided in Appendix B.

FWOP Scenario	Average Water Surface Elevations (feet)	Change in Average Water Surface Elevations from 2024 (feet)
2024	1,144.63	-
2049	1,144.46	-0.17
2074	1,144.25	-0.38
2124	1,143.41	-1.22

Table 28. Average Water Surface Elevations at Milford Reservoir

Note: The top of the multi-purpose pool is 1,144.4 feet. Elevations are in NGVD 1929. Represents average across the period of record.

There are two notable drought periods over the 100-period of analysis: 2044 (translates to past year of 1940), 2060 and 2061 (translates to past years of 1956 and 1957). There are three notable high water or flood years over the 100-year period of analysis: 2055 (translates to past year of 1951), 2097 (translates to past year of 1993), and 2123 (translates to past year of 2019).

Under both flooding and drought conditions, on average, pools levels are lower in FWOP 2049, 2074, and 2124 conditions than experienced under FWOP 2024 conditions (Table 29). During drought conditions, on average in 2044, 2060, and 2061, pool levels in 25 years (2049) are approximately over a foot lower, while in 50 and 100 years, pool levels are approximately three feet lower on average in 50 years and almost 13 feet lower than under 2124 FWOP conditions.

Table 29. Average Annual Water Surface Elevations During Drought and Flood Years

FWOP Scenario	Change in Average Water Surface Elevations from 2024 During Drought Years (feet)	Change in Average Water Surface Elevations from 2024 During Flood Years (feet)
2049	-1.37	-0.04
2074	-3.13	-0.16
2124	-12.71	-0.34

Note: The top of the multi-purpose pool is 1,144.4 feet NGVD 29

During the 2060-2061 drought period, under the FWOP 2024 scenarios, the pool is between 1,119 and 1,137 feet NGVD 29 (from seven to 25 feet lower than multi-purpose pool) between July 2060 and until June 2061 when it rises back to multi-purpose pool level.

Drought conditions, similar to those experienced in the mid-1950s, result in relatively lower water surface elevations (between five and 17 feet below multi-purpose pool) for almost two years between 2059 and 2061, which could result in severe implications for recreation as Milford Reservoir is expected to release more to meet the water quality targets on the Kansas River mainstem (i.e., Desoto and Topeka) because of the reduced storage available in Tuttle Creek Reservoir to support water quality targets. See Section 3.2.2.2.2 for more detail on drought impacts to recreation.

During drought or flood conditions, water surface elevations are not so low that the depth of the lake would cause impacts from water levels that are too low to recreate (see description on water surface elevations).

Under three notable high water or flood years over the 100-year period of analysis, as shown in Table 29, on average, water surface elevations are lower on average under the FWOP 2049, 2074, and 2124 conditions compared to FWOP 2024. During peak water surface elevations in these years, the difference among the water surface elevations under all FWOP scenarios is minimal.

The worst modeled future flood year in terms of visitation was in 2123 (compared to 2019) when, during the year, water surface elevations were above elevation 1,160 feet (see threshold table in existing conditions section) under all of the FWOP scenarios. In general, Milford Reservoir is closed to visitation when water surface elevations are 1,160 feet NGVD 29.

3.2.2.2. Changes in Visitation

This section describes how changes and lake elevations can potentially impact visitation at Milford Reservoir. Impacts from sediment are not discussed as Milford Reservoir does not loose significant storage over the 100 years of the FWOP. In the following sections the potential impacts to visitation are described compared to all visitation during typical conditions at the lake-elevation affected recreation areas under the baseline year, 2018. In 2018, 1,498,700 people visited recreation areas that are potentially impacted by lake elevations, which includes dispersed recreation. The study team also compared the impacted visitation to 2018 baseline visitation at all locations at Milford Reservoir. In 2018, visitation across Milford Reservoir was estimated to be 1,579,700.

3.2.2.1. Typical Precipitation Conditions

Drought conditions are the main driver of recreation impacts across the reservoir, although flood conditions and HABs can exacerbate these impacts to recreation further decreasing access and quality of recreation at the reservoir. Under typical precipitation visitation under the 100 years of the FWOP is assumed to remain similar to past visitation.

3.2.2.2. Drought Conditions

During drought conditions consistent with the historic drought of the mid-1950s, water surface elevations are considerably lower than the top of multipurpose pool across all FWOP scenarios (from seven to 25 feet lower than multi-purpose pool during this period) and considerably below thresholds important for recreation. In drought conditions, consistent with mid-1950s water conditions, all water-based access at recreation areas at the lake would be impacted under all FWOP scenarios. In addition, modeling shows periods of low to no storage at Milford Reservoir during extreme drought conditions. This would have multi-year impacts as the fishery would be impacted, recreation infrastructure (e.g., boat ramps) may require repairs and modifications, visitation would be severely impacted, and revenue sources to maintain the lakes would decrease.

Modeling of water surface elevations and critical lake elevations for recreation in the FWOP 2024 scenario show that in 2060 (modeled after 1956 drought conditions), visitation at the recreation areas that

could potentially be impacted by changes in lake elevations would be 1,080,300, a reduction of approximately 499,400 visitors from 2018 baseline conditions at lake-elevation affected recreation areas. The year 2044 (modeled after 1940 conditions) would have similar impacts to visitation.

3.2.2.3. Flood Conditions

Within the 100-year period of analysis, considerable flood events would occur under the FWOP in 2055 (modeled after 1951 conditions), 2097 (1993), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation in FWOP 2024, FWOP 2049, FWOP 2074, and FWOP 2124 conditions show considerable impacts to visitation at the recreation areas adjacent to the lake in these years (Table 30, Table 31, Table 32, and Table 33). A reduction in visitation at recreation areas impacted by changes in water surface elevations at Milford Reservoir in 2123, consistent with conditions experienced in 2019, indicates a potential visitation decrease of 81% compared to baseline conditions at Milford Reservoir (2018).

Table 30 below shows how flood conditions under the 2024 FWOP affect recreation in areas affected by changes in lake elevations by comparing visitation at those areas in modeled "flood years" (2055, 2097, and 2123) to baseline conditions (2018).

Flooding Years	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Percent Decrease in Visitation at Lake-Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018) at All Recreation Areas
Visitation under Baseline Conditions (2018)	1,498,700	-	-	1,579,700
2055	491,200	-1,007,500	-67%	-64%
2097	363,800	-1,135,000	-76%	-72%
2123	224,300	-1,274,400	-85%	-81%

	Table 30.	Annual	Changes i	n Visitation	Associated	with M	odeled I	Flood	Events,	FWOP	2024
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With flooding conditions, potentially more shore-based visitors could be impacted in the recreation areas around the lake as flooding can impact roads, trails and campgrounds with slightly higher reservoir elevations under future conditions compared to the FWOP 2024 scenario. If all water- and shore-based visitors in the recreation areas adjacent to the lake are impacted during flooding conditions, 1,498,700 visitors would be affected, representing 95% of visitation under baseline conditions at Milford Reservoir (2018). Table 31, Table 32, and Table 33 below show how flood conditions under the 2049, 2074, and 2124 FWOP scenarios affect recreation in areas affected by changes in lake elevations by comparing visitation at those areas in modeled "flood years" (2055, 2097, and 2123) to baseline conditions (2018).

Table 31.	Annual	Changes	in Visitation	Associated	with Modele	d Flood Events	s. FWOP 2049
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Flooding Years	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Percent Decrease in Visitation at Lake- Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018) at All Recreation Areas
Visitation under Baseline Conditions (2018)	1,498,700	-	-	1,579,700
2055	483,200	-1,015,500	-68%	-64%
2097	373,500	-1,125,300	-75%	-71%
2123	220,600	-1,278,100	-85%	-81%

Table 32. Annual Changes in Visitation Associated with Modeled Flood Events, FWOP 2074

Flooding Years	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Percent Decrease in Visitation at Lake- Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018) at All Recreation Areas
Visitation under Baseline Conditions (2018)	1,498,700	-	-	1,579,700
2055	486,500	-1,012,300	-68%	-64%
2097	374,800	-1,124,000	-75%	-71%
2123	237,700	-1,261,000	-84%	-80%

Table 33. Annual Changes in Visitation Associated with Modeled Flood Events, FWOP 2124

Flooding Years	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Percent Decrease in Visitation at Lake- Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018) at All Recreation Areas
Visitation under Baseline Conditions (2018)	1,498,700	-	-	1,579,700
2055	484,800	-1,014,000	-68%	-64%
2097	399,700	-1,099,100	-73%	-70%
2123	237,700	-1,261,000	-84%	-80%

Impacts on visitation under the three flood events could be high similar to past flood events. However, comparing water surface elevation impacts on visitation under the 2049, 2074, and 2124 FWOP scenarios during the three flood events, water surface elevations are minimally impacted (2049 - 0.1 foot increase to 0.1 foot decrease; 2074 - 0.0 to 0.3 foot decrease; and 2124 - 0.3 to 0.5 feet decrease) compared to

FWOP 2024. These minimal changes in water surface elevations under the three FWOP scenarios compared to FWOP 2024 during the three flood events has minimal effect on visitation compared to baseline visitation (2018) and shows some reduction in impacts as shown in Table 31, Table 32, and Table 33.

3.2.2.3. Changes in Economic Benefits

3.2.2.3.1. Consumer Surplus

Consumer surplus values are measured through the Corps' Unit Day Value (UDV) approach further described in Section 2.0. This section describes how changes and lake elevations and sediment conditions can potentially impact recreation consumer surplus values. Sediment deposition and relatively lower and higher water surface elevations have direct impacts on water-based visitors (boaters, swimmers, anglers) and indirect impacts to shore-based visitors for the recreation areas adjacent to the lake (termed lake-elevation affected recreation areas). In the following sections, we describe the potential impacts to consumer surplus values compared to all recreation values during typical conditions at the lake-elevation affected recreation areas under the baseline year, 2018.

Typical Precipitation Conditions

Visitation during baseline conditions at the recreation areas that are potentially impacted by lake elevations (including dispersed recreation) support an estimated \$16.4 million in consumer surplus value. The study team also compared the impacted consumer surplus values to baseline visitation and values (2018) at all locations at Milford Reservoir. In 2018, visitation across Milford Reservoir supported approximately \$17.2 million in consumer surplus values.³

Impacts from sediment are not discussed as Milford Reservoir does not lose significant storage over the 100 years of the FWOP.

Drought Conditions

The impacts to visitation during an extreme drought (below 1,118 feet NGVD 29) would impact all water-based visitation at lake-elevation impacted recreation areas under all FWOP scenarios. Drought conditions can also affect shore-based visitors if the lake shore is further away from camping and picnic area, or if shallow pools pose unappealing features or conditions (e.g., odors, swampy areas, mosquitoes, etc.). With elevations below 1,118 feet NGVD 29, an estimated 75% of shore-based visitors could be impacted (see Table 27).

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled droughts years of 2044 (modeled after 1940 conditions), reduced visitation would translate to a potential loss in consumer surplus values during drought conditions of approximately \$4.6 million annually (Table 34). These reductions in visitation in the recreation areas impacted by changes in lake elevations represent an annual decrease of 28% compared to 2018 baseline conditions.

³ Consumer surplus values are estimated with recreation visitor day and the Corps' UDV approach. In the modeling effort, visits were converted to recreation visitor days to apply the UDV using an estimate of average number of days per trip at the Kansas City District lakes to estimate consumer surplus. In this appendix, visitation is presented and described for consistency, and not recreation visitor days.

Table 34. Annual Visitation and Consumer Surplus Changes Associated with Drought Events,FWOP 2024

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake- Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus at Lake-Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus (2018)
Baseline condition (2018)	1,498,700	-	\$16.4 million	\$16.4 million	\$17.2 million
2044	1,080,300	-418,400	-\$4.6 million	-28%	-27%
2060	1,082,200	-416,500	-\$4.6 million	-28%	-27%

Consumer Surplus is expressed in FY22\$

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2049 conditions show that in modeled droughts years of 2044 (modeled after 1940 conditions) and 2060 (modeled after 1956 conditions), reduced visitation would translate to a potential loss in consumer surplus values during drought conditions of approximately \$4.6 to \$4.9 million annually (Table 35). These reductions in visitation in the recreation areas impacted by changes in lake elevations represent an annual decrease of 28 to 30% compared to 2018 baseline conditions.

Table 35. Annual Visitation and Consumer Surplus Changes Associated with Drought Events,FWOP 2049

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake- Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus at Lake-Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus (2018)
Baseline condition (2018)	1,498,700	-	\$16.4 million	\$16.4 million	\$17.2 million
2044	1,057,000	-441,700	-\$4.9 million	-30%	-28%
2060	1,079,400	-419,300	-\$4.6 million	-28%	-27%

Consumer Surplus is expressed in FY22\$

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2074 conditions show that in modeled droughts years of 2044 (modeled after 1940 conditions) and 2060 (modeled after 1956 conditions), reduced visitation would translate to a potential loss in consumer surplus values during drought conditions of approximately \$4.8 to \$4.9 million annually (Table 36). These reductions in visitation in the recreation areas impacted by changes in lake elevations represent an annual decrease of 29% to 30% compared to 2018 baseline conditions.

Table 36. Annual Visitation and Consumer Surplus Changes Associated with Drought Events,FWOP 2074

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake- Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus at Lake-Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus (2018)
Baseline condition (2018)	1,498,700	-	\$16.4 million	\$16.4 million	\$17.2 million
2044	1,052,300	-446,400	-\$4.9 million	-30%	-28%
2060	1,065,800	-432,900	-\$4.8 million	-29%	-28%

Consumer Surplus is expressed in FY22\$

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2124 conditions show that in modeled droughts years of 2044 (modeled after 1940 conditions) and 2060 (modeled after 1956 conditions), reduced visitation would translate to a potential loss in consumer surplus values during drought conditions of approximately \$5.8 to \$7.2 million annually (Table 37). These reductions in visitation in the recreation areas impacted by changes in lake elevations represent an annual decrease of 35 to 44% compared to 2018 baseline conditions. These larger impacts in the 2124 FWOP are from decreases in the average pool elevation as Milford Reservoir is expected to release more to meet the water quality targets on the Kansas River mainstem (i.e., Desoto and Topeka) because of the reduced storage available in Tuttle Creek Reservoir under the 2124 FWOP to support water quality targets.

Table 37. Annual Visitation and Consumer Surplus Changes Associated with Drought Events,FWOP 2124

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake- Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus at Lake-Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus (2018)
Baseline condition (2018)	1,498,700	-	\$16.4 million	\$16.4 million	\$17.2 million
2044	969,400	-529,300	-\$5.8 million	-35%	-34%
2060	840,000	-658,700	-\$7.2 million	-44%	-42%

Consumer Surplus is expressed in FY22\$

Flood Conditions

Within the 100-year period of analysis, considerable flood events would occur in 2055 (modeled after 1951 conditions), 2097 (1993), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss in consumer surplus values during flood conditions of between \$11.0 and \$13.9 million in consumer surplus values, representing a decrease between 67 and

85% of total consumer surplus at lake-elevation affected areas at Milford Reservoir under baseline conditions (Table 38 below). There could also be impacts to visitation at the recreation areas below the dam (e.g., Outlet Park) with potentially higher releases from the dam and localized flooding below the dam, although these impacts were not modeled.

Flood Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake- Elevation Affected Areas	Percent Decrease in Visitation at Lake-Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018)
Baseline condition (2018)	1,498,700	-	\$16.4 million	\$16.4 million	\$17.2 million
2055	491,200	-1,007,500	-\$11.0 million	-67%	-64%
2097	363,800	-1,135,000	-\$12.4 million	-76%	-72%
2123	224,300	-1,274,500	-\$13.9 million	-85%	-81%

Table 38. Annual Visitation and Consumer Surplus Changes Associated with Modeled Flo	od
Events, FWOP 2024	

Consumer Surplus is expressed in FY22\$

Under FWOP 2049, 2074, and 2124 conditions, water surface elevations are slightly lower on average compared to FWOP 2024 conditions during modeled years of 2055, 2097, and 2123 (Table 39, Table 40, and Table 41). During peak water surface elevations in these years, the difference among the water surface elevations under all FWOP scenarios is minimal (Table 39, Table 40, and Table 41).

Table 39. Annual Visitation and Consumer Surplus Changes Associated with Modeled FloodEvents, FWOP 2049

Flood Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake- Elevation Affected Areas	Percent Decrease in Visitation at Lake-Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018)
Baseline condition (2018)	1,498,700	-	\$16.4 million	\$16.4 million	\$17.2 million
2055	483,200	-1,015,500	-\$11.1 million	-68%	-65%
2097	373,500	-1,125,200	-\$12.3 million	-75%	-72%
2123	220,600	-1,278,100	-\$13.9 million	-85%	-81%

Consumer Surplus is expressed in FY22\$

Table 40. Annual Visitation and Consumer Surplus Changes Associated with Modeled FloodEvents, FWOP 2074

Flood Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake- Elevation Affected Areas	Percent Decrease in Visitation at Lake-Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018)
Baseline condition (2018)	1,498,700	-	\$16.4 million	\$16.4 million	\$17.2 million
2055	486,500	-1,012,200	-\$11.0 million	-67%	-64%
2097	374,800	-1,123,900	-\$12.3 million	-75%	-72%
2123	237,700	-1,261,000	-\$13.8 million	-84%	-80%

Consumer Surplus is expressed in FY22\$

Table 41. Annual Visitation and Consumer Surplus Changes Associated with Modeled FloodEvents, FWOP 2124

Flood Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake- Elevation Affected Areas	Percent Decrease in Visitation at Lake-Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018)
Baseline condition (2018)	1,498,700	-	\$16.4 million	\$16.4 million	\$17.2 million
2055	484,800	-1,013,900	-\$11.0 million	-67%	-64%
2097	399,700	-1,099,000	-\$12.0 million	-73%	-70%
2123	237,700	-1,261,000	-\$13.8 million	-84%	-80%

3.2.2.3.2. Regional Economic Benefits

Regional economic impacts are estimated through the Corp's RECONS model and further described in Section 2. This section describes how changes and lake elevations and sediment conditions can potentially impact regional economic benefits (jobs and income) to adjacent communities. Visitors spend their money in local communities, providing regional economic benefits in these communities. Sediment deposition and relatively lower and higher water surface elevations have direct impacts on water-based visitors (boaters, swimmers, anglers) and indirect impacts to shore-based visitors for the recreation areas adjacent to the lake (termed lake-elevation affected recreation areas). In the following sections, we describe the potential impacts to regional economic benefits from reduced visitation compared to regional economic benefits supported under baseline conditions in 2018. Consistent with visitation in 2018, 1,579,700 visitors support 411 jobs and \$12.7 million in labor income in the local economy under baseline conditions (see Table 42). In the recreation areas potentially affected by changes in lake elevations under baseline conditions, 1,498,700 visitors support 387 jobs and \$12.0 million in labor income.

Typical Precipitation Conditions

Drought conditions are the main driver of recreation impacts across the reservoir, although flood conditions and HABs can exacerbate these impacts to recreation further decreasing access and quality of recreation at the reservoir. Under typical precipitation visitation under the 100 years of the FWOP is assumed to remain similar to past visitation.

Impacts from sediment are not discussed as Milford Reservoir does not lose significant storage over the 100 years of the FWOP.

Drought conditions

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled drought years of 2044 (translates to past year of 1940) and 2060 (modeled after 1956 conditions), reduced visitation would lead to a potential loss of 116 jobs and \$3.7 million during drought conditions under 2024 FWOP compared to baseline conditions (Table 42). These reductions in economic benefits represent a 28 to 29% decrease in jobs from total jobs supported from all visitor spending at Milford Reservoir under baseline conditions (411 annual jobs). Droughts can also have lasting impacts to tourism business depending on the timing of the recovery and resiliency of the businesses, including the reservoir refilling, the re-establishment of the fishery, steps to mitigate losses in visitation, and the demand for recreation at the lake.

Table 42. Annual Visitation and Changes in Regional Ec	conomic Benefits Associated with Drought
Events, FWOP 2024	

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake-Elevation Affected Areas from Baseline Visitation	Reduction in Jobs at Lake- Elevation Affected Areas	Reduction in Labor Income at Lake-Elevation Affected Areas	Percent Decrease in Jobs and Income from Baseline Conditions
Baseline condition (2018)	1,498,700	-	387	\$12.0 million	411 jobs; \$12.7 million in labor income
2044	1,080,300	-418,400	-117	-\$3.7 million	-29%
2060	1,082,200	-416,500	-116	-\$3.6 million	-28%

Labor income is expressed in FY22\$

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2049 conditions show that in modeled drought years of 2044 (translates to past year of 1940) and 2060 (modeled after 1956 conditions), reduced visitation would lead to a potential loss of 117 to 127 jobs and \$3.7 to \$4.0 million during drought conditions under 2024 FWOP compared to baseline conditions (Table 43). These reductions in economic benefits represent a 29% to 31% decrease in jobs from total jobs supported from all visitor spending at Milford Reservoir under baseline conditions (411 annual jobs).

Table 43. Annual Visitation and Changes in Regional Economic Benefits Associated with DroughtEvents, FWOP 2049

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake-Elevation Affected Areas from Baseline Visitation	Reduction in Jobs at Lake- Elevation Affected Areas	Reduction in Labor Income at Lake-Elevation Affected Areas	Percent Decrease in Jobs and Income from Baseline Conditions
Baseline condition (2018)	1,498,700	-	387	\$12.0 million	411 jobs; \$12.7 million in Iabor income
2044	1,057,000	-441,700	-127	-\$4.0 million	-31%
2060	1,079,400	-419,300	-117	-\$3.7 million	-29%

Labor income is expressed in FY22\$

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2074 conditions show that in modeled drought years of 2044 (translates to past year of 1940) and 2060 (modeled after 1956 conditions), reduced visitation would lead to a potential loss of 123 to 129 jobs and \$3.9 to \$4.1 million during drought conditions under 2024 FWOP compared to baseline conditions (Table 44). These reductions in economic benefits represent a 31% to 32% decrease in jobs from total jobs supported from all visitor spending at Milford Reservoir under baseline conditions (411 annual jobs).

Table 44. Annual Visitation and Changes in Regional Economic Benefits Associated with DroughtEvents, FWOP 2074

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake-Elevation Affected Areas from Baseline Visitation	Reduction in Jobs at Lake- Elevation Affected Areas	Reduction in Labor Income at Lake-Elevation Affected Areas	Percent Decrease in Jobs and Income from Baseline Conditions
Baseline condition (2018)	1,498,700	-	387	\$12.0 million	411 jobs; \$12.7 million in labor income
2044	1,052,300	-446,400	-129	-\$4.1 million	-32%
2060	1,065,800	-432,900	-123	-\$3.9 million	-31%

Labor income is expressed in FY22\$

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2124 conditions show that in modeled drought years of 2044 (translates to past year of 1940) and 2060 (modeled after 1956 conditions), reduced visitation would lead to a potential loss of 155 to 188 jobs and \$4.9 to \$6.0 million during drought conditions under 2024 FWOP compared to baseline conditions (Table 45). These reductions in economic benefits represent a 39% to 47% decrease in jobs from total jobs supported from all visitor spending at Milford Reservoir under baseline conditions (411 annual jobs). Milford Reservoir is expected to release more to meet the water quality targets on the Kansas River mainstem (i.e., Desoto and Topeka) because of the reduced storage available in Tuttle Creek Reservoir to support water quality targets under the 2124 FWOP causing substantial decreases in jobs and income compared to the baseline and the 2024 FWOP.

Table 45. Annual Visitation and Changes in Regional Economic Benefits Associated with DroughtEvents, FWOP 2124

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Jobs at Lake- Elevation Affected Areas	Reduction in Labor Income at Lake- Elevation Affected Areas	Percent Decrease in Jobs and Income from Baseline Conditions
Baseline condition (2018)	1,498,700	-	387	\$12.0 million	411 jobs; \$12.7 million in labor income
2044	969,400	-529,300	-155	-\$4.9 million	-39%
2060	840,000	-658,700	-188	-\$6.0 million	-47%

Labor income is expressed in FY22\$

Flood Conditions

Within the 100-year period of analysis, considerable flood events would occur in 2055 (modeled after 1951 conditions), 2097 (1993), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss of 273-338 jobs and \$8.5 to \$10.5 million in labor income, representing a decrease between 67% and 83% of total jobs supported by visitor spending at Milford Reservoir under baseline conditions (Table 46). There could also be impacts to visitation at the recreation areas below the dam (e.g., Outlet Park) with potentially higher releases from the dam and localized flooding below the dam, although these impacts were not modeled.

Table 46. Annual Visitation and Changes in Regional Economic Benefits Associated with FloodEvents, FWOP 2024

Flood Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Jobs at Lake- Elevation Affected Areas	Reduction in Labor Income at Lake- Elevation Affected Areas	Percent Decrease in Jobs and Income from Baseline Conditions
Baseline condition (2018)	1,498,700	-	387	\$12.0 million	411 jobs; \$12.7 million in labor income
2055	491,200	-1,007,500	-273	-\$8.5 million	-67%
2097	363,800	-1,135,000	-308	-\$9.6 million	-76%
2123	224,300	-1,274,400	-338	-\$10.5 million	-83%

Labor income is expressed in FY22\$

Under the FWOP 2049, 2074, and 2124 scenarios, water surface elevations are slightly lower on average compared to FWOP 2024 conditions during modeled years of 2055, 2097, and 2123. During peak water surface elevations in these years, the difference among the water surface elevations under all FWOP scenarios is minimal and the impacts to the regional economic benefits (i.e., jobs and labor income) remain fairly consistent compared FWOP 2024 for the modeled years of 2055, 2097, and 2123.
The results of the 100-year FWOP scenario (2124) are included in Table 47 as comparison. FWOP 2049 and 2074 have very similar results to the FWOP 2124.

Flood Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake-Elevation Affected Areas from Baseline Visitation	Reduction in Jobs at Lake- Elevation Affected Areas	Reduction in Labor Income at Lake- Elevation Affected Areas	Percent Decrease in Jobs and Income from Baseline Conditions
Baseline condition (2018)	1,498,700	-	387	\$12.0 million	411 jobs; \$12.7 million in labor income
2055	484,800	-1,014,000	-275	-\$8.6 million	-68%
2097	399,700	-1,099,100	-300	-\$9.4 million	-74%
2123	237,700	-1,261,100	-335	-\$10.4 million	-82%

Table 47. Annual Visitation and Changes in Regional Economic Benefits Associated with Flood Events, FWOP 2124 (Labor income is expressed in FY22\$)

Damages, Revenues, and Fees to States

Visitation to Milford Reservoir contributes considerable revenue to the state to maintain parks. Revenue is collected through park entrance fees, camping fees, hunting and fishing license revenues, concessionaire fees. In 2018, the revenues associated with Milford Reservoir were \$505,000, fourth in revenue in the state of Kansas.⁴ At Milford Reservoir in 2019, these revenues were \$418,000, a reduction of 17% from 2018 revenues due to reduced visitation from flooding events.

Hunting and fishing license sales are also important for the state, bringing in \$31.2 million in 2018 across the state, although this data is not available by lake. In general, these revenues vary over time and are typically proportional to visitation at the lakes. As described in this section, sediment deposition, droughts, and flooding conditions can have considerable impacts on this visitation and therefore revenue sources for the state. The evaluation indicates that drought conditions could result in an annual decrease of visitation up to 33% of baseline conditions (2018), while flooding impacts would have larger impact, impacting up to 81% of visitation under baseline conditions. These impacts would continue to occur overtime when droughts or flooding occur, with their occurrences becoming more frequent with climate change.

During these extreme events, the state and USACE often incur costs to repair damages, conduct small, scale dredging, and other actions to repair or maintain infrastructure. Therefore, the state has less revenues coming in, with increased expenses, often impacting state coffers for years.

Estimated costs for repairs of recreational infrastructure associated with damage from the 2019 flood at USACE-managed recreation areas of Milford Reservoir were \$740,000. The impacts at the KDWP state parks at Milford Reservoir include damages to docks, fish cleaning stations, and campsites, as well as actions to remove debris are at \$435,000. These damages are likely to continue to occur in the future with extreme events.

⁴These fees and revenues, generally paid by visitors to federal and state governments, are included in the estimate of economic output in described in Section 3.4.1.2.3.

3.2.2.4. Navigation Releases

Navigation releases from Milford and Perry reservoirs can be made from the water supply storage volume that has not been called into service by the State of Kansas. All of the multipurpose pool storage is under contract for water supply to the state of Kansas in the two reservoirs. Until all storage is called into service, multipurpose objectives of the remaining storage can be used to supplement Missouri River flows for navigation within operating limits. If 100% of the water supply volume is called into service for Milford and Perry reservoirs, navigation releases from the water supply volume would not occur at these reservoirs. Navigation flow support is provided by Milford Reservoir in the FWOP scenario for 2024 but not for the 2049, 2074, and 2124 as it is anticipated that the remaining storage will be called into service by the state of Kansas before these three timeframes.

3.2.2.4.1. Typical Precipitation Conditions

Navigation releases under the FWOP 2024 results in increased frequency of pool elevations below the top of multipurpose pool elevation. Higher pool elevations in the navigation FWOP 2024 scenario are the same as those under the non-navigation FWOP 2024 scenario. The 2049, 2074, and 2124 FWOP scenarios did not provide navigation support flows, but some small impacts are assessed because of Tuttle Creek Reservoir providing the navigation support flows which then requires Milford Reservoir to make additional releases to support water quality targets. Under the FWOP 2124 scenario Milford Reservoir is already supporting most of the water quality releases as the multipurpose pool as Tuttle Creek Reservoir is almost full of sediment with little remaining storage volume (see Appendix B).

Due to the lower pool elevations in the multipurpose pool in the FWOP 2024 scenario with navigation releases, modeled visitation is on average three to 3.3% lower than the FWOP scenarios without navigation releases across all these typical precipitation years. These changes also have similar implications for consumer surplus values and regional economic effects. Under the FWOP 2024 scenario with navigation releases, lower pool elevations in these typical precipitation years could result in reduced visitation on average of approximately 47,500 visitors, with an associated reduction in consumer surplus values of \$465,000 compared to the FWOP 2024 scenario without navigation releases. There would be small decreases in regional economic benefits as well.

3.2.2.4.2. Drought Conditions

In the two modeled drought years (2044 and 2060), average reservoir elevations under FWOP 2024 with navigation releases in these years are approximately 2 feet lower than reservoir elevations under FWOP 2024 without navigation releases.

3.2.2.4.3. Flood Conditions

In the three modeled flood years (2055, 2097, and 2123), average reservoir elevations under all FWOP scenarios with navigation releases show very little change compared to the scenarios without navigation releases, resulting in no change in visitation under FWOP scenarios with navigation releases and FWOP scenarios without navigation releases. There would be no effect of navigation releases on consumer surplus values and regional economic benefits during flood conditions.

3.2.2.5. Water Quality

Excess nutrients can lead to HABs under ideal growing conditions. HABs have impacted Milford Reservoir since 2011 with HAB warnings impacting recreation seven of the last 10 years. Due to their ability to possibly release toxins detrimental to human and animal health, along with their ability to destroy aquatic habitat and life, and their unsightliness, HABs have the potential to further decrease recreation in the future at Milford Reservoir. With extreme HAB conditions, warnings are issued along

with closures for public access. Persistent warnings can also deter visitors from coming to the lake. Milford Reservoir has a below average water residence time compared to other USACE reservoirs in the basin, particularly in late summer, leading to an increase in soluble nutrient concentrations that can lead to increased algal growth and the potential for HABs. Deteriorating water quality could eventually lead to increased prevalence of HABs in Milford Reservoir with adverse impacts to visitors in the future. Watershed conservation efforts have increased in priority for state and local rankings to address Milford Reservoir hypereutrophic conditions and chronic HABs. Impacts from HABs has been implicated in local economic impact from decrease in tourism/recreational visitation and are expected to continue in the future (Appendix G).

As described it is estimated that approximately 468 acre-feet of sediment accumulates on average annually at Milford Reservoir. Sediment will continue to accumulate with an expected additional 2.5% loss of the multipurpose pool over the next 25 years and a 4% loss over the next 50 years (Appendix D). Reduced volume means less dilution and can equate to higher concentration of nutrients stored in the lake system. With the expected low amount of sediment expected to accumulate in Milford Reservoir issues related to reduced dilution will not likely impact water quality or recreation at Milford Reservoir.

The primary water quality threats at Milford Reservoir for eutrophication are nutrients, sediment, toxic cyanobacteria blooms, and dissolved oxygen sags. Milford Reservoir has been listed as impaired by KDHE and is classified as hypereutrophic due to excessive nutrients. A total daily maximum load (TMDL) was developed for Milford Reservoir to prioritize reduction of nutrients in the watershed to address water quality and frequent HAB issues. Measures that are being tested to reduce the frequency of HABs include a plan for adjustments to the lake level management plan for a functional drawdown during the spring and summer months. This measure will continue to be tested to determine if this operational change may be a tool to mitigate HABs. These impacts are expected to continue and potentially increase (see Appendix G) in the future causing reduced visitation and reduced visitor experience during periods when there are restrictions, warnings, or closure of favored recreation areas at Milford Reservoir.

All reservoirs in the watershed, including Milford Reservoir, will likely experience increasing effects of aging. Future water quality within watershed lakes is dependent on multiple influencing factors, some of which are challenging to predict and/or estimate. It can be assumed that continued, and increasing fertilizer use, will continue to influence the water quality of runoff, groundwater, streams, and lakes. Continued and enhanced water quality impairment may be expected at Milford Reservoir. Consistent with existing conditions, storm events generating high run-off volumes will continue to transport the majority of sediment and nutrient loads to the reservoir. Based on a watershed-wide pattern of increasing in-lake total phosphorus concentrations there is a potential for continued eutrophication (high algal productivity) at Milford Reservoir with the likelihood of increased transport of quantities of sediment and nutrients based on an assessment of runoff/streamflow, sediment yield, and TN and TP yield under climate change runoff to Milford Reservoir is expected to have a high increase leading to a high increase in sediment yield and TP yield and a medium increase in TN yield that could lead to increased levels of eutrophication.

Water residence times were estimated for Milford Reservoir (Appendix G). A reduction in residence time results in less time for nutrient and sediment constituents to settle within reservoirs and then passing them downstream. Reservoirs with higher sedimentation rates that are losing large portions of their multipurpose pool have the largest decreases in residence time expected in the future. Milford Reservoir does not have a high sedimentation rate expected over the next 100 years and is estimated to have a reduction in residence time of 12% under the FWOP 2124. There will likely be a seasonality to these

reductions in residence time with greater reductions during the wetter periods and increases during the drier periods.

3.2.2.6. Angling and Sport Fishery

The future of the fishery for Milford Reservoir looks steady for now. However, several factors that fisheries biologists need to continue to monitor in the future are impacts of reservoir aging on fish populations, flooding impacts, increased sedimentation, invasive species presence, and habitat fragmentation. The ability to use the best science available can lead to creating the best management practices to be able to maintain these fish populations in a constantly changing environment. These fish populations are very important to all anglers who utilize Milford Reservoir. Therefore, being able to understand how these populations could be impacted in the future can aid in better management of these fish species (Appendix E).

3.3. Perry Lake

Perry Lake is located on the Delaware River 4.5 miles northwest of Perry, Kansas and 17 miles east of Topeka (Figure 13 below). It was built by the USACE for flood control, navigation, water supply/quality, recreation, fish and wildlife purposes.

3.3.1. Existing Conditions

3.3.1.1. Recreation Facilities and Visitation

Perry Lake hosts eight parks, seven of which are managed by USACE and one state park managed by KDWP. Below highlights the numerous recreational opportunities available at Perry Lake:

- Marinas
- Boat Ramps
- Yacht Club
- Beaches
- Hiking/Biking/Equestrian Trails

- Disk Golf Course
- Off-road Recreational Vehicle Trail
- Archery Area
- Camping Areas
- Wildlife Areas

According to USACE and KDWP data, for the year 2018, visitation to the lake was estimated at 785,900 people. In 2018, Perry State Park accounted for the most visitation at Perry Lake at 32%, followed by Rock Creek Marina & Resort at 15%, and Perry Marina at 10%. Additionally, there is a private camp operated by the Boy Scouts at Perry Lake, that is not included in the visitation estimates.

In terms of prevalent activities at Perry Lake, camping was the most popular activity at the lake, accounting for 25% of all activities. Other popular activities include water contact activities (19%), sightseeing (13%), picnicking (12%), boating (10%), and fishing (5%) (USACE VERS Data 2018). Perry Lake hosts many special events including fishing tournaments, Frisbee golf, and bike races. There are also Regattas held every year at Perry Lake. Special event visitation accounted for about 3% of total visitation in 2018. According to iSportsman data there were 4,269 hunting visits (with full compliance – meaning that users were reporting as required) in wildlife areas and 854 wildlife viewing visits representing 0.41% and 0.08% of total activities respectively.



Figure 13. Perry Lake Recreation Areas

3.3.1.2. Sport Fisheries

This section provides a summary of sport fishing at Perry Reservoir. Additional information is provided in the Reservoir Fisheries Technical Report (see Appendix E). The general objective of fisheries management at Perry Reservoir is to optimize the quality and diversity of angling opportunities. Specific management activities include tailoring fish harvest regulations to changes in sportfish population trends, stocking fish to enhance population abundance as needed, construction of fish attractors to enhance angling opportunities, and other activities for maintaining/improving angling access. From March-August the lake elevation can increase to support spawning habitat for bass, crappie, and sauger.

The number of anglers visiting Perry Reservoir is relatively high when compared to other Kansas reservoirs due to its proximity to major metropolitan areas. According to the last creel survey, total angler trips were approximately 57,731. The reservoir sees anglers traveling from not just the population centers of Kansas but from all corners, with 91 communities represented. There were also many anglers visiting Perry Reservoir from neighboring or distant states. Of the eleven states, other than Kansas, which anglers hailed from, the majority came from Missouri (Appendix E).

Anglers at Perry Reservoir usually harvest at least some fish, with only 12% of anglers not harvesting any fish during their trips Harvest is dominated by white crappie and followed by channel catfish, similar to angler preference. White bass comes in third for fish harvested. Largemouth and smallmouth bass anglers on Perry Reservoir tend to be more catch-and-release oriented, choosing to release more of their catch in hopes that they grow to trophy size.

Perry Reservoir is filling in with sediment to the detriment of the fish and the anglers who pursue them, as well as other interest groups that use the reservoir. Sedimentation of the reservoir reduces the storage capacity and also the fishable areas while also filling in any unique, fish attracting bathymetric features (e.g., river channels). Decreased storage capacity will likely result in Perry Reservoir being more responsive to heavy rains, exhibiting more drastic rises than were experienced when the river was impounded over fifty years ago. The more drastic and frequent fluctuations will make the establishment and development of aquatic vegetation even more difficult. Further degradation of existing fish habitat will be countered with the installation of artificial fish habitat, but natural features are likely more appealing to fish and it is unknown if the rate of replacement can match the rate of degradation.

This reservoir is within close proximity to the majority of the large population centers of Kansas; a onehour drive from the heart of Kansas City. The reservoir is already known for its exceptional crappie fishing and receives a good deal of traffic from tournament bass fishing, which is a growing sport. There is also the possibility that in the next ten years, Perry Reservoir could develop a high-quality blue catfish fishery. If this population takes hold, it is likely to receive increased pressure from metropolitan catfishermen who would like a closer destination than Milford Reservoir. The reintroduction of paddlefish to Perry Reservoir and the Delaware River could also result in an increase of recreational anglers. If this population takes hold and recreational snagging is allowed, there could be a large number of anglers travel to the reservoir's upper reaches or spillway in the spring when these fish make their spawning runs.

While angler use may remain constant or increase, access to the reservoir may decrease. The upper end of the reservoir north of the Highway 92 bridge is closed to access half of the year as a refuge but during periods when this area is accessible anglers utilize this area. Continued siltation at the upper end of the reservoir may hinder angler access to that portion of the reservoir during periods when the area is open to public access resulting in crowding at more southern boat access areas. Similarly, more frequent or more drastic water level fluctuations could result in most, if not all, boat ramps being closed to angler access.

Water level management will also continue to be crucial to sport fisheries and anglers. Available habitats and types, and successful sportfish reproduction and survival, can all be positively or negatively impacted by the timing of water releases and magnitudes thereof. High releases around sauger spawning could be detrimental both on the local and statewide scale, too. KDWP is dependent on this adult sauger population to produce and stock sauger and saugeye across the entire state of Kansas.

3.3.1.3. Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

In May of 2019, Perry Lake was severely impacted by flooding, forcing the closure of 6 boat ramps, Slough Creek Park, Rock Creek Park, Old Town Park campground, and Perry Beach. The entire area typically used by recreation visitors was impacted by flooding either from closures of roads or loss of electrical power. During the spring flood event, Perry Reservoir was above multipurpose pool for over 60 days, with a max crest of 30 feet above multi-purpose pool (USACE 2020).

Annual visitation in 2019 at Perry Lake was 26% lower compared to annual visitation in 2018. This decrease was mostly driven by a 39% decrease in summer visitation (May-August) and a further 60% decrease in fall (Sep-Dec) visitation (USACE and KDWP 2018-2019). Perry Lake staff indicated that during the 2019 flood, wellfields were also inundated at Perry Lake at 15 feet over normal elevation. Due to flooding, USACE campgrounds were closed all year, entire roadways were closed, and equestrian trails were too muddy to use. Additionally, the repairs to many recreation areas were slow due to the COVID-19 pandemic, with only 60% of recreation areas opened at the start of the 2020 recreation season. Many more "primitive" areas weren't open until Labor Day weekend of 2020.

In 2012 and 2013 the majority of Kansas suffered a drought. The multi-purpose pool at Perry was 73.9% full in January of 2013. In August of 2018, water surface levels were four to six inches below multi-purpose pool levels, exposing hazards which caused safety concerns for boaters (USACE, August 2018). Wildlife areas tend to be minimally impacted by low water events, and low water sometimes makes it easier for hunting access.

2011 was the last time Perry State Park closed due to HABs impacts. In the summer of 2021, a HAB warning was issued for Perry Lake. However, this is unusual and according to staff, Perry doesn't tend to have issues with HABS.

3.3.1.4. Critical Lake Elevations for Recreation

Lake elevations are an important factor for water- and shore-based recreation at Perry Reservoir. Working with the USACE lake staff and KDWP fisheries experts, critical lake elevations for recreation were identified at Perry Reservoir as well as the corresponding impacts to visitation. These lake elevations are used in the recreation modeling effort to assess the impacts to visitation and economic benefits under FWOP conditions. Other important water surface elevations for the reservoirs are part of the lake level management plans, which specify lake elevations to support fish and wildlife. It is important to note that water surface elevation and depth of water are not equivalent. For example, the water surface elevation may rise five feet above the multi-purpose pool, but if 10 feet of sediment were to accrue at the bottom of the lake, then the lake's depth would decrease five feet. This is not accounted for quantitatively in the model, but it is important to consider it qualitatively when assessing impacts of water surface elevation and depth to recreation, especially boating and fishing. Future reservoir sedimentation for Perry Reservoir and any impacts to recreation are described in Section 3.3.2.

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Lake Elevations (feet)	<886 ft	886-888 ft	888-895; multi- purpose pool is 891.5 ft	895-897.5 ft	897.5-903.5 ft	>903.5 ft
Visitation Impacts	No boating access, all ramps unusable. Marinas impacted and Yacht Club required to move a majority of boats to deeper water.	Boat ramps usable starting at elevation 886. No pumping of water into wetlands below conservation pool, impacting waterfowl hunting.	No Issues	Boating access issues at State Park ramps starting at 895. 25% of lower elevation campsites affected. Limited fishing and recreational boating due to closure of approximately 50 percent of boat ramp access.	Water based recreation basically closed due to limited recreational access at boat ramps. Multiple campsites and campground roads affected. Beach areas closed; all water-based recreation affected. Very limited fishing and boating access.	Elevations above 903.5 impacts roadways at the State Park and closes primitive areas. No public water access available. Entire campgrounds closed due to no access from flooded roads. Marina and Yacht Club access is closed.
Quality of Recreation Effects	Exposed shorelines with debris, rocks, steep banks. Underwater hazards exposed.	Boat ramps usable with caution, potential underwater hazards.	No Impacts	Some campsite reductions due to flooding.	Debris from flooding can become a safety concern.	Most areas are closed.

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¹ The information in this table was developed with input from USACE and KDWP staff familiar with Perry Reservoir. Lake Elevations are in NGVD 1929 **Table 49. Percent of Reservoir Impacted by Critical Lake Elevation Thresholds**

Lake Elevations (feet)	<886 ft	886-888 ft	888-895; multi- purpose pool is 891.5 ft	895-897.5 ft 897.5-903.5 ft		>903.5 ft
Water-based Visitor Impacts	100%	75%	0%	50%	100%	100%
Shore-based Visitor Impacts	25%	20%	0%	25%	75%	100%

¹ The information in this table was developed with input from USACE and KDWP staff familiar with Perry Reservoir. Lake Elevations are in NGVD 1929

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3.3.2. Future Without Project Conditions

This section considers the impact of future conditions on recreation, including sediment, water surface elevations, water quality and fishery conditions. The first few sections describe how sediment and water surface elevations will change under the four FWOP scenarios, and how these changes will impact visitation and economic benefits. The FWOP scenarios that include navigation releases are considered in Section 3.3.2.5. A qualitative evaluation of how changes in water quality and fishery conditions will affect recreation in the future is provided in Sections 3.3.2.6 and 3.3.2.7, respectively.

3.3.2.1. Changes in Sediment and Water Surface Elevations

This section considers three precipitation conditions and their impacts on visitation and economic benefits under the FWOP scenarios. These precipitation conditions are typical precipitation periods, drought periods, and high water or flooding periods. To identify the drought and flood years, average annual elevations were analyzed across the period of record. Two years were chosen to evaluate flood conditions, with average annual elevations at Kanopolis Lake above 903 feet NGVD 29, and two years were chosen to evaluate drought conditions, with *average annual* elevations below 886 feet NGVD 29. See Tables 48 and 49 for a description of impacts to recreation at different lake elevation thresholds.

Drought years include:

- 2060 (1956)
- 2061 (1957)

Flood years include:

- 2097 (1993)
- 2123 (2019)

Typical years include all other years.

3.3.2.1.1. Sediment Conditions

Sedimentation has and will continue to impact recreation at Perry Lake. In terms of USACE managed areas, Rock Creek and Slough Creek is where most visitation currently occurs, and they will likely not be impacted by sediment within the planning timeframe. Old Town park will likely be lost to sediment accumulation within the next few years. Perry State Park will probably remain open, however there could be changes in the types of uses by visitors. The marinas will be impacted by sediment accumulation in the future, which would greatly impact boating at Perry. By 2124, the entire north end of the lake is projected to be filled with sediment if nothing is done to mitigate the effects of sedimentation.

Dredging boat ramps can potentially mitigate/counter the effects of sedimentation and maintain access for boat ramps. However, the enactment of this temporary measure is uncertain and dependent on funding availability. Without any management actions (e.g., dredging, reallocation), all boating and marina access to Perry Lake would no longer be available starting in 2124. Lake managers have indicated that these conditions would result in a severe reduction in visitation if sediment on boat ramps and the marina are not mitigated. Not only would water-based visitors be affected, but also those visitors that come to view or be next to the lake. Boaters, anglers, and other water-contact activities at the recreational areas around the lake accounted for 367,200 visits in 2018, 34% of total visitation. Other shore-based visitors could also be affected, including special event attendees, campers, picnickers, and sightseers. Shore-based visitors at the recreation areas around the lake accounted for 418,700 or 66% of total visitation in 2018. The impacted visitation and years when access would be lost at the various recreation areas are summarized in Table 50. Figures 14-17 below show sediment accumulation overtime in Perry Lake.

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Figure 14. Perry Reservoir Baseline Depths – 2024



Figure 15. Perry Reservoir Future Depths with Projected Sedimentation – 2049 (25 Years)



Figure 16. Perry Reservoir Future Depths with Projected Sedimentation – 2074 (50 Years)



Figure 17. Perry Reservoir Future Depths with Projected Sedimentation – 2124 (100 Years)

	2018 Total Visitation	2018 Water- based Visitation	% Water-based Visitors	Approx Year of Loss in Water- based Access
Old Town	13,100	4,600	35%	2024
Longview	5,300	1,900	36%	2074
Perry Yacht Club	8,800	4,000	45%	2124
Perry Park	47,800	20,600	43%	2124
Rock Creek Marina	119,500	60,900	51%	2124
Recreation Areas Affected by Sediment in the lake*	194,500	92,000	47%	-
Rec Areas affected by lake elevation	712,600	242,300	34%	-
Project-wide	785,900	367,200	34%	-

Table 50. Recreation Areas Affected by Sediment and Lake Elevations at Perry Reservoir

*Includes Longview, Old Town, Perry Park, Rock Creek Marina and Perry Yacht Club

**Includes admin/ visitor center, KDWP management area, Perry State Park, Old Military trail, Outlet, Rock Creek, Slough Creek, Thompsonville and Perry Marina

3.3.2.1.2. Water Surface Elevations

Table 51 summarizes the average lake elevations over the 100-year period of analysis under the four FWOP scenarios. On average, the lake's average water surface elevation is expected to increase very slightly over time. Additional information is provided in Appendix B.

FWOP Scenario	Average Water Surface Elevations (ft)	Change in Average Water Surface Elevations from 2024 (ft)
2024	892.08	-
2049	892.10	0.02
2074	892.13	0.05
2124	892.11	0.03

Table 51. Average Water Surface Elevations at Perry Reservoir Across the Period of Record

Note: The top of the multi-purpose pool is 891.5 feet NGVD 29

Table 52. Average Annual Water Surface Elevations During Drought and Flood Years

FWOP Scenario	Change in Average Water Surface Elevations from 2024 During Drought Years	Change in Average Water Surface Elevations from 2024 During Flood Years
2049	-0.43	+0.05
2074	-0.79	-0.04
2124	-2.81	+0.18

Note: The top of the multi-purpose pool is 891.5 feet NGVD 29

During the 2060-2061 drought period, under the FWOP 2024 scenario, the pool elevation drops from 882 feet NGVD 29 to a low of 876 feet NGVD 29 between Jan 2060 and Feb 2061 before gradually returning to multi-purpose pool level in Jul 2061. This could result in severe implications for recreation with current and future sediment conditions.

Sediment is already creating problems for water-based access at Old Town Park on the north end of the lake. This problem of sedimentation at the lake will worsen, with Corps sediment modeling indicating that in 100 years, no recreation areas adjacent to the lake will remain boat-ramp accessible. Because water surface elevations would be considerably lower during drought periods than the multi-purpose pool elevation, all recreation areas may not be accessible to boats and may increase safety concerns across the lake compared to typical precipitation water surface elevations.

Under the notable high water or flood years over the 100-year period of analysis, as shown in Table 52, on average, water surface elevations will not change by much under the FWOP 2049, 2074, and 2124 conditions compared to FWOP 2024, although on any given point over the flood years, the difference between FWOP 2124 water surface elevations and FWOP water surface elevations can be up to three feet lower.

The worst flood years in terms of surface elevation are 2097 and 2123, when, for most of the year, water surface elevations are above elevation 903.5 feet NGVD 29, even reaching elevations of 920 feet NGVD 29 for periods of time. In general, Perry Lake is closed to visitation when water surface elevations are 903 feet NGVD 29 or higher.

3.3.2.2. Changes in Visitation

This section describes how changes in lake elevations and sediment conditions can potentially impact visitation. Changes in lake elevations and sediment have direct impacts on water-based visitors (boaters, swimmers, anglers) and indirect impacts to shore-based visitors for the recreation areas adjacent to the lake (termed lake-elevation affected recreation areas). The following sections will describe the potential impacts to visitation compared to all visitation during typical conditions at the lake-elevation affected recreation areas under the baseline year, 2018. In 2018, 712,600 people visited recreation areas that are potentially impacted by changing lake elevations in the future. We also compare the impacted visitation to 2018 baseline visitation at all locations at Perry Lake. In 2018, visitation across Perry Lake was estimated to be 785,900.

3.3.2.2.1. Typical Precipitation Conditions

Due to the considerable impacts to water-based visitors from sediment deposition impacting access, a sediment map-based assessment was conducted for typical precipitation conditions.

In 2024, there are five recreation areas adjacent to Perry Lake with water-based access: Old Town, Longview, Perry Yacht Club, Perry Park, and Rock Creek Marina (Table 50). By 2124, water-based access will be considerably reduced at all five of the recreation areas and no boat ramps will be accessible due to the accumulation of sediment (Figures 14, 15, 16, and 17). By 2124, An estimated 92,000 water-based recreators would be affected, and if it is assumed that all water- and shore-based visitation at these recreation areas shift to another lake or opt not to recreate, 194,500 visitors would be impacted (see Table 50). These visitors represent 12% and 25%, respectively, of visitors under baseline conditions (2018) at Perry Lake. If these recreation areas were converted to accommodate only shore-based activities, perhaps with construction of trails or off-highway vehicle (OHV) areas, a new mix of visitors would be anticipated, although it is difficult to ascertain how visitation would ultimately be impacted.

3.3.2.2.2. Drought Conditions

During drought conditions, notably the period of 2060-2061, water surface elevations are up to 15 feet lower than the top of multipurpose pool across all FWOP scenarios, and considerably below thresholds important for recreation. During these conditions, all water-based access at recreation areas at the lake would be impacted under all FWOP scenarios.

The impacts to visitation during an extreme drought under all FWOP scenarios would be similar, though not as pronounced, to the visitation impacts due to sediment accumulation as described under the FWOP 2049, 2074, and 2124 scenarios above under typical precipitation conditions. An estimated 92,000 (water-based) and 194,500 (both water- and shore-based) visitors could be impacted by reduced lake access during these types of conditions. Additional visitation could also be affected in areas that are not directly impacted by changes in lake elevations, such as in the recreation areas below the dam, although these

impacts are not included in the estimates. For example, if lower releases impact fishing conditions on fishing success below the dam, there could be additional impacts to recreation and reductions in visitation not captured in the abovementioned estimates.

Drought Years	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake-Elevation Affected Areas from Baseline Visitation	Percent Decrease in Visitation at Lake-Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018) at All Recreation Areas	
Visitation under Baseline Conditions (2018)	712,600	-	-	785,900	
2060	2060 345,500 -367,1		-52%	-47%	
2061	600,100	-112,500	-16%	-14%	

Table 53 Annua	l Changes in Visitat	ion Associated With	Modeled Drought Years	5 FWOP 2024
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Modeling of water surface elevations and critical lake elevations for recreation in the FWOP 2024 scenario show that in 2060 (modeled after 1956 drought conditions), the worst projected drought year, visitation at the recreation areas that could potentially be impacted by changes in lake elevations would be 345,500, a reduction of approximately 367,100 visitors from 2018 baseline conditions at lake-elevation affected recreation areas.

3.3.2.2.3. Flood Conditions

Within the 100-year period of analysis, considerable flood events would occur under the FWOP in 2097 (1993) and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation in FWOP 2024 conditions show considerable impacts to visitation at the recreation areas adjacent to the lake in these years. A reduction in visitation at recreation areas impacted by changes in water surface elevations at Perry Lake in 2123, consistent with conditions experienced in 2019, indicates a potential visitation decrease of 92 percent compared to baseline conditions at Perry Lake (2018). In comparison, state park data indicated that 2019 visits were 23 percent lower than in 2018, mostly due to flooding conditions.

There could also be impacts to visitation at the recreation areas below the dam with potentially higher releases from the dam and localized flooding below the dam and safety closures could occur; these impacts are not captured in these figures. Table 54 below shows how flood conditions affect recreation in areas affected by changes in lake elevations by comparing visitation at those areas in modeled "flood years" (2097 and 2123) to baseline conditions (2018).

Flooding Years	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake-Elevation Affected Areas from Baseline Visitation	Percent Decrease in Visitation at Lake-Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018) at All Recreation Areas
Baseline Conditions (2018)	712,600	-	-	785,900
2097	81,900	-630,700	-89%	-80%
2123	59,900	-652,700	-92%	-83%

Table FA	A	Chamman		A a a a a latad	N/					2024
1 able 54.	Annual	Changes	in visitation	Associated	with N	loaelea	FIOOD I	Events.	FVVUP	ZUZ4
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During flooding conditions, up to roughly 90% of visitors at lake-elevation-affected areas could be impacted, and potentially even more shore-based visitors could be impacted in the recreation areas around the lake as flooding can impact roads, trails and campgrounds with slightly higher reservoir elevations under future conditions compared to the FWOP 2024 scenarios.

3.3.2.3. Changes in Economic Benefits

3.3.2.3.1. Consumer Surplus

Consumer surplus values are measured through the Corps' Unit Day Value (UDV) approach further described in Section 2.0. This section describes how changes and lake elevations and sediment conditions can potentially impact recreation consumer surplus values. Sediment deposition, relatively lower water surface elevations, and relatively higher water surface elevations have direct impacts on water-based visitors (boaters, swimmers, anglers) and indirect impacts to shore-based visitors for the recreation areas adjacent to the lake (termed lake-elevation-affected recreation areas). In the following sections, we describe the potential impacts to consumer surplus values when visitation is impacted. Visitation during baseline conditions at the recreation areas that are potentially impacted by lake elevations (including dispersed recreation) support an estimated \$7.8 million in consumer surplus value. We also compare the impacted consumer surplus values to baseline visitation and values (2018) at all locations at Perry Lake. In 2018, visitation across Perry Lake supported approximately \$8.5 million in consumer surplus values.⁵

Typical Precipitation Conditions

Reductions in visitation at Perry Lake due to sediment deposition would result in lower consumer surplus values as described in this section. By 2124, water-based access will be considerably reduced at Old Town, Longview, Perry Yacht Club, Perry Park, and Rock Creek Marina due to the accumulation of sediment (Figure 17). An estimated 92,000 (water-based) and 194,500 (both water- and shore-based) visitors could be impacted by reduced lake access at the recreation areas affected by sediment. It is possible that some of the visitors engaged in water-based activities could shift to shore-based activities; however, it is likely that some of the visitors, both water- and shore-based visitors, to these recreation areas would choose to visit other lakes or opt not to recreate because water access is no longer available, shorelines are covered in silt and sediment, and other adverse aesthetic impacts are occurring (e.g., odors, reduced fishing success). If all water-based visitors no longer came to Perry Lake, there would be an annual loss of \$922,600 in consumer surplus (CS) values. Shore-based visitors at Perry Lake contribute an estimated \$1,040,400 in consumer surplus value, and it is likely a portion of these visitors would also be impacted by 2124 sediment conditions by the reduced ability to view and recreate near the lake or by decreased aesthetic qualities (Table 55 below).

Table 55. Perry Reservoir Visitation and Consumer Surplus Impacted by Sediment Deposition
During Typical Precipitation Conditions under FWOP Scenarios

Perry Lake	Total Visitation and CS Values	Water Based Visitation and CS Values	Shore Based Visitation and CS Values
Baseline Visitation (2018)	785,900	367,200	418,700
Baseline Consumer Surplus Values (2018) Consumer Surplus is expressed in FY22\$	\$8,500,000	\$3,971,500	\$4,528,500

⁵ Consumer surplus values are estimated with recreation visitor day and the Corps' UDV approach. In the modeling effort, visits were converted to recreation visitor days to apply the UDV using an estimate of average number of days per trip at the Kansas City District lakes to estimate consumer surplus. In this appendix, visitation is presented and described for consistency, and not recreation visitor days.

Perry Lake	Total Visitation and CS Values	Water Based Visitation and CS Values	Shore Based Visitation and CS Values
Potential Losses in Visitation in 2124	-194,500	-92,000	-102,500
Potential Losses in Consumer Surplus in 2124	-\$1,963,000	-\$922,600	-\$1,040,400

Drought Conditions

The impacts to visitation during an extreme drought would impact all water-based visitation at lakeelevation impacted recreation areas under all FWOP scenarios, a loss of \$2.7 million in consumer surplus values. Drought conditions can also affect shore-based visitors if the lake shore is further away from camping and picnic area, or if shallow pools pose unappealing features or conditions (e.g., odors, swampy areas, mosquitoes, etc.) With elevations below 886 feet NGVD 29, an estimate 25% of shore-based visitors could also be impacted (see Table 48 and Table 49), leading to a potential loss of \$260,100 in addition to the loss of water-based consumer surplus for a total loss of approximately \$3 million. In the modeled drought year of 2060, there would be a reduction in visitation of 367,100 and consumer surplus of \$4.1 million compared to baseline conditions at the lake-elevation affected areas (Table 56).

Table 56. Annual Visitation and Consumer Surplus Changes Associated with Drought Events,FWOP 2024

Drought Year	ModeledReduction inVisitation atVisitation atRecreationLake-AreasElevationAffected byAffectedChanges inAreas fromLakeBaselineElevationsVisitation		Reduction in Consumer Surplus at Lake- Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus at Lake-Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus (2018)
Baseline condition (2018)	712,600	-	\$7,800,000	-	\$8,500,000
2060	345,500	-367,100	-\$4,065,100	-52%	-48%
2061	600,100	-112,500	-\$1,294,900	-16%	-15%

Consumer Surplus is expressed in FY22\$

Flood Conditions

Within the 100-year period of analysis, considerable flood events would occur in 2097 (1993) and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss in consumer surplus values during flood conditions of approximately \$7 million in consumer surplus values (Table 57 below). There could also be impacts to visitation at the recreation areas below the dam with potentially higher releases from the dam and localized flooding below the dam, although these impacts were not modeled.

Table 57. Annual Visitation and Consumer Surplus Changes Associated with Modeled Flood Events, FWOP 2024 (Consumer Surplus is expressed in FY22\$)

Flood Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake- Elevation Affected Areas	Percent Decrease in Visitation at Lake- Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018)
Baseline condition (2018)	712,600	-	\$7,800,000	-	\$8,500,000
2097	81,900	-630,700	-\$6,933,000	-89%	-80%
2123	59,900	-652,700	-\$7,163,900	-92%	-83%

3.3.2.3.2. Regional Economic Benefits

Regional economic impacts are estimated through the Corp's RECONS model and further described in Section 2. This section describes how changes in lake elevations and sediment conditions can potentially impact regional economic benefits (jobs and income) for adjacent communities. Visitors spend their money in local communities, providing regional economic benefits in these communities. Sediment deposition and relatively lower and higher water surface elevations have direct impacts on water-based visitors (boaters, swimmers, anglers) and indirect impacts to shore-based visitors for the recreation areas adjacent to the lake (termed lake-elevation affected recreation areas). In the following sections, we describe the potential impacts to regional economic benefits from reduced visitation compared to regional economic benefits supported under baseline conditions in 2018. Consistent with visitation in 2018, 785,900 visitors support 249 jobs and \$10.5 million in labor income in the local economy under baseline conditions. In the recreation areas potentially affected by changes in lake elevations under baseline conditions, 712,600 visitors support 230 jobs and \$9.7 million in labor income.

Typical Precipitation Conditions

Reductions in visitation at Perry Lake due to sediment deposition would result in lower regional economic benefits to adjacent communities as described in this section. By 2124, water-based access would be considerably reduced at Longview, Old Town, Perry Park, Rock Creek Marina, and Perry Yacht Club due to the accumulation of sediment (Figure 17). If all visitors no longer came to Perry Lake due to these recreation areas being unavailable, there would be an annual loss of 62 jobs and \$2.6 million in labor income.

Table 58. Perry Reservoir Visitation and Regional Economic Benefits Impacted During Typical Precipitation Conditions

Impacts	Visits	Jobs	Labor Income	Gross Regional Product	Economic Output
Baseline Conditions (2018)	785,900	249	\$10.5 million	\$17.7 million	\$31.7 million
2124 Water- and shore-based Impacts	-194,500	-62	-\$2.6 million	-\$0.4 million	-\$0.8 million

Labor income is expressed in FY22\$

Drought conditions

The impacts to visitation during an extreme drought would impact all water-based visitation at lakeelevation impacted recreation areas under all FWOP scenarios. If these visitors did not come to the lake, there would be a loss in annual regional economic benefits of 77 jobs and \$3.2 million in labor income compared to baseline conditions. Droughts can also have lasting impacts to tourism business depending on the timing of the recovery and resiliency of the businesses, including the reservoir refilling, the reestablishment of the fishery, steps to mitigate losses in visitation, and the demand for recreation at the lake.

Table 59. Annual Visitation and Changes in Regional Economic Benefits Associated with Dre	ought
Events, FWOP 2024	_

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Jobs at Lake- Elevation Affected Areas	Reduction in Labor Income at Lake- Elevation Affected Areas
Baseline condition (2018)	712,600	-	230	\$9.7 million
2060	345,500	-367,100	-150	-\$6.5 million
2061	600,100	-112,500	-44	-\$1.9 million

Labor income is expressed in FY22\$

Flood Conditions

Within the 100-year period of analysis, considerable flood events would occur in 2097 (1993) and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss of 216 jobs and \$9.1 million in labor income (Table 60). There could also be impacts to visitation at the recreation areas below the dam with potentially higher releases from the dam and localized flooding below the dam, although these impacts were not modeled.

Table 60. Annual Visitation and Changes in Regional Economic Benefits Associated with Flood Events, FWOP 2024

Flood Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Jobs at Lake- Elevation Affected Areas	Reduction in Labor Income at Lake- Elevation Affected Areas	
Baseline condition (2018)	aseline condition 712,600		230	\$9.7 million	
2097	81,900	-630,700	-210	-\$8.9 million	
2123	59,900	-652,700	-216	-\$9.1 million	

Labor income is expressed in FY22\$

3.3.2.4. Damages, Revenues, and Fees to States

Visitation to Perry Lake contributes considerable revenue to the state to maintain parks. Revenue is collected through park entrance fees, camping fees, hunting and fishing license revenues, concessionaire fees. In 2018, the revenues associated with Perry Lake were \$299,000.⁶

Hunting and fishing license sales are also important for the state, bringing in \$31.2 million in 2018 across the state, although this data is not available by lake. In general, these revenues vary over time and are typically proportional to visitation at the lakes. As described in this section, sediment deposition, droughts, and flooding conditions can have considerable impacts on this visitation and therefore revenue sources for the state. The evaluation indicates that with flooding conditions could result in an annual decrease of visitation up to 83 percent of baseline conditions (2018) at Perry Reservoir (Table 54).

During these extreme events, the state and USACE often incur costs to repair damages, conduct small scale dredging, and other actions to repair or maintain infrastructure. Therefore, the state has less revenues coming in, with increased expenses, often impacting state coffers for years.

Estimated costs for repairs of recreational infrastructure associated with damage from the 2019 flood at USACE-managed recreation areas of Perry Lake were \$703,500. The impacts at the KDWP state parks at Perry Lake for recreational damages were estimated to be \$5,200. These damages are likely to continue to occur in the future with extreme events.

3.3.2.5. Navigation Releases

Navigation releases from Milford and Perry reservoirs can be made from the water supply storage volume that has not been called into service by the State of Kansas. All of the multipurpose pool storage is under contract for water supply to the state of Kansas in the two reservoirs. Until all storage is called into service, multipurpose objectives of the remaining storage can be used to supplement Missouri River flows for navigation within operating limits. If 100% of the water supply volume is called into service for Milford and Perry reservoirs, navigation releases from the water supply volume would not occur at these reservoirs.

3.3.2.5.1. Typical Precipitation Conditions

Navigation releases under the FWOP 2024 results in increased frequency of pool elevations below the top of multipurpose pool elevation. Average reservoir elevations under the FWOP 2024 scenario with navigation releases are modeled to be approximately 0.5 feet lower than reservoir elevations under the FWOP 2024 scenario without navigation releases. This would cause noticeable, but not extremely large decreases in visitation, consumer surplus, and regional economic development.

3.3.2.5.2. Drought Conditions

In the modeled drought period (2060-2061), average reservoir elevations under FWOP 2124 with navigation releases in these years are approximately 1.5 feet lower than reservoir elevations under FWOP 2024 without navigation releases. All of the effects of drought described in Sections 3.3.2.2.2 and 3.3.2.3 could be not only realized, but dramatically exacerbated by navigation releases.

3.3.2.5.3. Flood Conditions

In the modeled flood years (2097 and 2123), average reservoir elevations under all FWOP scenarios with navigation releases show very little change compared to the scenarios without navigation releases,

⁶These fees and revenues, generally paid by visitors to federal and state governments, are included in the estimate of economic output in described in Section 3.3.2.4.

resulting in no change in visitation under FWOP scenarios with navigation releases and FWOP scenarios without navigation releases. There would be no effect of navigation releases on consumer surplus values and regional economic benefits during flood conditions.

3.3.2.6. Water Quality

All reservoirs in the Kansas River Watershed, including Perry Lake, will likely experience increasing effects of aging. Future water quality within the Kansas River watershed lakes is dependent on multiple influencing factors, some of which are challenging to predict and/or estimate. It can be assumed that continued, and increasing fertilizer use, will continue to influence the water quality of runoff, groundwater, streams, and lakes. Approximately 40% of the total watershed area is classified as Grassland/Herbaceous and Pasture/Hay, much of which is used as rangeland/stock areas for livestock in the watershed. The Kansas Department of Agriculture (2021) publishes total numbers of livestock (cattle, sheep, hogs), and increasing trends in the numbers of animals that require feed and produce increased quantities of manure, indicate the potential for worsening water quality in downstream lakes.

Continued sediment loading will diminish storage capacity, deliver increased quantities of nutrients and pollutants, and compound effects of eutrophication. Continued and enhanced water quality impairment may be expected at Perry Lake. Consistent with existing conditions, storm events generating high run-off volumes will continue to transport the majority of sediment and nutrient loads to Perry Lake. Deposited and suspended sediments affect aquatic habitat and life, contributing to reduced abundance and diversity via smothered spawning sites, inhospitable macroinvertebrate habitat, increased turbidity, reduced light availability, inhibited phytoplankton and macrophyte growth, diminished sight and filter-feeding, and water temperature effects.

The nutrients nitrogen and phosphorus are abundantly available throughout the Kansas River Watershed. A watershed-wide pattern of increasing in-lake total phosphorus concentrations suggests potential for continued eutrophication (high algal productivity) at Kansas River Watershed reservoirs. Phosphorus is often considered a nutrient that limits primary productivity (e.g., phytoplankton, aquatic plants), although nutrient limitation of phytoplankton growth is dependent on species and may vary depending on time and location. Too much phosphorus can cause increased growth of algae and aquatic plants, which can result in decreased levels of dissolved oxygen, a process called eutrophication. Observed decreasing total nitrogen to total phosphorus (TN:TP) ratios may indicate an enhanced opportunity for seasonal harmful algal bloom (HAB) – algal blooms that produce toxins detrimental to human and animal health – issues as some flourish under conditions with elevated phosphorus availability and water temperature. Based on 30 years of annual testing at Perry Lake, total phosphorus at the dam has been increasing and can be anticipated to increase in the future as fertilizer use in agriculture increases. With increased levels of phosphorus in the future, storm events could result in algal blooms in Perry Lake, although a number of other factors also impact the development of HABs (e.g., the ability to keep water moving through the reservoir).

Due to their ability to possibly release toxins detrimental to human and animal health, along with their ability to destroy aquatic habitat and life, and their unsightliness, HABs have the potential to further decrease recreation in the future at Perry Lake. With extreme HAB conditions, warnings are issued along with closures for public access. Persistent warnings can also deter visitors from coming to the lake. While historically not an issue, deteriorating water quality could eventually lead to increased prevalence of HABs in Perry Lake with adverse impacts to visitors in the future.

Water residence times were estimated for Perry Reservoir (Appendix G). A reduction in residence time results in less time for nutrient and sediment constituents to settle within reservoirs and then passing them

downstream. Reservoirs with higher sedimentation rates that are losing large portions of their multipurpose pool have the largest decreases in residence time expected in the future. Perry Reservoir has a moderately high sedimentation rate expected over the next 100 years and is estimated to have a reduction in residence time of 40% under the FWOP 2124 scenario. There will likely be a seasonality to these reductions in residence time with greater reductions during the wetter periods and increases during the drier periods.

3.3.2.7. Angling and Sport Fishery

Sediment conditions will continue to have adverse impacts for the fishery at Perry Lake. The loss of habitat and water volume due to sedimentation impact the lake's capacity to produce fish. Sedimentation will continue to occur and has the potential to dramatically reduce recreational use of the reservoir, especially for anglers. Dredging can be used to clear sediment from boat ramps to improve access but can also be used to improve shoreline depth for bank anglers and to improve fish habitat, although these efforts have been minimally effective due to rapid sediment accumulation. The high effort and cost of dredging will also likely limit these projects to select locations. The role of turbidity on the fishery will likely only increase as water volume continues to decrease.

In addition, it is likely that dynamic water level events will continue to play a prominent role in determining sportfish densities. Emigration of fish during periods of elevated release rates will likely occur in the future similar to past events that will lead to periodic reductions in sportfish species and a potential need for additional stocking. Anglers are able to utilize some of the sportfish that regularly emigrate out of the lake. There are several factors that fisheries biologists need to continue to monitor in the future are impacts of reservoir aging on fish populations, flooding impacts, increased sedimentation, invasive species presence, and habitat fragmentation. The ability to use the best science available can lead to creating the best management practices to be able to maintain these fish populations in a constantly changing environment.

3.4. Tuttle Creek Lake

Tuttle Creek Dam (Figure 18 below) is located on the Big Blue River, 12.3 miles upstream of the confluence of the Big Blue and Kansas Rivers. Tuttle Creek Lake is located primarily in Riley and Pottawatomie Counties in Kansas with the far upper end of the lake extending into Marshall County, Kansas. The dam site is situated five miles north of Manhattan, Kansas, 60 miles west of Topeka, 125 miles west of Kansas City, and 130 miles south of Lincoln, Nebraska.



Figure 18. Tuttle Creek Reservoir Recreation Map

3.4.1. Existing Conditions

3.4.1.1. Recreation Facilities and Visitation

There are four state parks managed by KDWP at Tuttle Creek Reservoir: Fancy Creek State Park, Randolph State Park, Cedar Ridge State Park, and River Pond State Park. There is one county park, and the remainder of the recreation areas are managed by USACE. Below highlights the recreational infrastructure and opportunities available at Tuttle Creek Reservoir (Tuttle Creek Lake Master Plan, 2019; USACE Fastfacts):

- Recreation Areas
- Boat Ramps
- Marina Slips
- Camping Sites
- Swimming Areas

- Shooting Range
- Archery Range
- Trails
- Off-road Vehicle (ORV) Area
- Spillway Cycle Area

According to combined USACE and KDWP data, visitation at the lake in 2018 was 1,016,600. This includes hunting and wildlife area visitation. Visitation in 2018 contributed \$756,000 in revenue to the state in terms of park fees, entrance fees, camping fees and other revenues.

The state parks at Tuttle Creek Reservoir accounted for 61% of visitation in 2018, with most of the use at River Pond State Park, followed by Cedar Ridge State Park. Fancy Creek State Park visitation has recently been affected be sedimentation (see description below). Dispersed recreation, recreation that takes place outside of the established recreation areas, accounted for approximately 3% of visitation in 2018 (USACE VERS). In terms of types of recreational activities at Tuttle Creek Reservoir, camping and sightseeing were the most popular activities at the lake in 2018, accounting for 36% and 15% of total activities, respectively. Boating, angling, and water-contact activities accounted for 8%, 5%, and 13% of all activities, respectively (USACE VERS 2018). According to 2018 iSportsman data, hunting visits were 2,983 (with full compliance) and wildlife visits were 597 representing 0.49% and 0.10% of total activities.

At the start of each new year, Tuttle Creek Reservoir, along with many other Kansas state parks hosts a "First Day Hike" for the public to enjoy the New Year outdoors (KDWP). Special recreation events like this one, account for 2% of annual activity participation at the lake.

3.4.1.2. Sport Fisheries

This section provides a summary of sport fishing at Tuttle Creek Reservoir. Additional information is provided in the Reservoir Fisheries Technical Report (see Appendix E). From March to September the lake managers allow the elevation to increase to support spawning habitat for crappie.

Reservoir sportfish species accounts and factors affecting their abundance and distribution are included below. It is notable that inherent variability exists in statistics generated from fish population sampling efforts. Changes in reservoir water level, abundance and distribution of flooded terrestrial vegetation, turbidity or lack thereof, etc. can alter fish behavior and feasibility of deploying sampling gear, thus potentially increasing variability of sampling results. As a result, sampling results must be viewed with a degree of skepticism, require interpretation by workers utilizing the data, and often require a series of greater than one year for representative trends to become apparent (KDWP 2020a).

The reservoir has provided some exceptional angling opportunities during these years, but frequent dynamic water level events have restricted the angling potential of the lake due to high fish emigration rates and inconsistent recruitment of many of the popular sportfish species. High water levels in fall of

2018 prevented the completion of the fall standardized annual fish sampling. Exceptional flood conditions in 2019 prevented all forms of fish sampling in the lake that year. Shoreline access available to anglers is quite limited at Tuttle Creek Reservoir when compared to other lakes. This is in part to due to how the purchase of the land for the lake was based on elevation, instead of traditional section lines. This makes many shoreline areas landlocked by private property and inaccessible to the general public by land or road. Bank fishing is further restricted when water levels are elevated as this submerges most of the easily accessible shoreline. High water also limits access by causing road closures, further distancing anglers from the water. Flood debris along the shoreline serves as additional hinderance to shore bound anglers. Many of the historically popular bank fishing locations were in the upper end of the reservoir and have since been loss due to the excessive sedimentation. There are few shoreline areas that have been developed in the lower reaches of the lake that would provide suitable bank fishing access. There is likely resistance to invest in shoreline improvements that could be loss due to the expectation that future high-water events will negate any development efforts (KDWP 2020a).

Boat usage is much lower at Tuttle Creek Reservoir then at other local impoundments and there are multiple factors contributing to this. The lake currently has a low number of boat ramps available to public access. Numerous boat ramps have been loss to sedimentation, road closures, or lack of maintenance. Once the lake is ten feet above conservation pool, which is a fairly common occurrence at this lake, there is only one developed boat ramp still accessible to the public. Only two of the existing ramps regularly have a dock available and one of these has been closed since the 2019 flood event. Docks at boat ramps facilitate easier loading/unloading of boats and the absence of docks at ramps likely contributes to lower participation rates, especially for solitary boaters and people with movement limitations or disabilities. Another factor that limits boat usage is high-water events increasing boating hazards in the form of floating debris which probably negatively influences a boat angler's decision to use this lake. As to the actual fishing experience, it is considered harder to have a successful fishing trip at Tuttle Creek Reservoir than at many other Kansas lakes. Rapid water level fluctuations and dynamic shifts in water turbidity makes it more difficult to predict fish behavior and reduces angler success per trip (KDWP 2020a).

The lake was stocked an additional eight times from 2007 to 2016 with a total of 145,715 blue catfish fingerlings. The blue catfish population at Tuttle Creek is evaluated with gill nets and with a low pulse electrofishing effort. These sampling efforts through the years indicate that half of the new stocking efforts had limited to poor recruitment. However, the 2013, 2014 and 2015 stockings showed moderate to good survival and the 2011 stocking had excellent recruitment (KDWP 2020a).

Tuttle Creek Reservoir is prone to large and frequent water level fluctuations, which causes difficulty in following a water level management plan. The approved plan for the reservoir has not changed significantly since the late 1990's. This plan calls for water levels to be 3 feet below conservation pool in the winter, at conservation pool in the spring and through the summer months with a fall rise of 4 feet for waterfowl habitat. This plan is not ideal for the production of a good fishery, but this is mostly irrelevant as water levels at this impoundment rarely adhere to the plan (KDWP 2020a).

Spring waters levels in 2018 were fairly stable and release rates were moderate during the summer. This should have been beneficial to spawning success and limit emigration of many fish species. Unfortunately, evaluation of potential benefits was limited because the traditional netting and fall electrofishing efforts were not conducted due to water levels being approximately 25 feet high during the sampling season. Starting in early September, the drainage saw abundant precipitation which caused water levels to rise 20 feet in five days. Highest water level in 2018 was recorded at 29 feet above conservation pool on October 26th. A rainy fall facilitated the reservoir being at least 15 feet high for most

of the last four months of the year. This led to outflow rates being well above normal for that time of year with 44 days of release rates at 10,000 to 14,000 cfs. High release rates during October has facilitated emigration of saugeye and young channel catfish in the past (KDWP 2020a).

Much of the Midwest suffered through historic flooding in 2019 and Tuttle Creek Reservoir was no exception. Due to flooding throughout the region, there was a need to retain water in reservoirs to alleviate issues downstream. Therefore, much of the high spring runoff was kept in Tuttle Creek and water levels reached 25 feet above normal multi-purpose pool elevations by mid-March. The month of April saw 40 feet above normal multi-purpose pool elevations and then flood waters crested at a new record high at the end of May at just over 60 feet above conservation pool. At this point, the lake was quadruple the normal surface acres and held over seven times the typical volume. Water levels were elevated through the entire growing season, not dipping below 35 feet high until November, and finally reached plan levels by mid-December. For over 100 days, release rates were at 10,000 cfs or more, with the peak at a record setting 30,000 cfs. The prominent sportfish species at Tuttle Creek were chosen due to their higher flood tolerance, but this was an unprecedented event that may have lingering impacts to the fish populations (KDWP 2020a).

Thankfully, 2020 was a mild year in the Tuttle Creek water level history. The lake did reach 15 feet above normal multi-purpose pool in both June and August, but the changes in water elevations were rather slow allowing successful fish spawning for several species. Release rates were at 10,000 to 14,000 cfs for 27 total days, but fish loss was likely less of a factor due to low densities of the susceptible species from the exceptionally high emigrations the previous year (KDWP 2020a).

White crappie is the most popular sportfish at Tuttle Creek Reservoir, and the species has the ability to draw large numbers of anglers to the reservoir during good fishing conditions. Maintaining a robust crappie fishery for angler harvest is the primary fisheries management objective at Tuttle Creek Reservoir. Compared to other northeastern Kansas reservoirs, Tuttle Creek Reservoir has typically had a lower abundance of crappie. Tuttle Creek Reservoir has supported a productive channel cat fishery. Angler preference for this species is high in the reservoir and in the tail water habitats. Through the history of the lake, white bass have been a popular sportfish drawing anglers that seek this species. However, the white bass population has fluctuated in sample abundance, which is not uncommon for the white bass fish in Kansas impoundments. At Tuttle Creek Reservoir, the rise and fall in white bass density is associated with spring river inflows during the spawning period and with gizzard shad abundance, a prevalent prey species of the white bass. The 2019 flood was devastating to the species as was documented in the 2020 sampling record with only one white bass being collected. Tuttle Creek Reservoir was stocked with a total of 16,263 paddlefish from 1992 to 1995. It was hoped that these fish could establish a self-sustaining population through natural reproduction to create a fishery. This was not the case as there was never any evidence of paddlefish spawning in the drainage.

3.4.1.3. Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

Sedimentation has had a profound impact on recreation at Tuttle Creek Lake. To date, three parks (Swede Creek, Garrison, and Baldwin) and numerous private/community docks and ramps have been closed as a direct impact of sedimentation, lost lake access, and associated decreased demand. Two state parks (Fancy Creek and Randolph) have been converted to primarily land-based recreation with the loss of boat ramps and a marina, reducing visitation at these areas.

At Tuttle Creek Lake, sediment is accumulating and filling in the delta, with the most severe impacts at the northern end of the lake. Mitigation of recreational impacts has included small scale dredging of boat ramps and small coves, park closures, conversion of park areas to land-based recreation, and

concentration of recreational development towards the southern recreation areas of the lake (Tuttle Creek Lake Master Plan 2019). With increasing sediment deposition, shallower pools limit boating access to ramps and around the lake, especially during relatively drier periods and associated lower lake elevations.

Sedimentation can also affect the natural resources in the lake. Suspended sediments carry nutrients and metals which accelerate eutrophication and can limit fishery production for native and sportfish species. Sediment deposition can also create land-based recreation opportunities, providing terrestrial and wildlife habitat (especially wetlands), and expanding opportunities for wildlife viewing and hunting (USACE Tuttle Creek Master Plan, 2019).

Both flooding and drought have the potential to impact public access to recreation. Like other lakes and reservoirs in the region, Tuttle Creek Lake experienced flooding during the spring and summer of 2019. Although the state park at Tuttle Creek Lake did remain open throughout the flooding, most recreation areas around the lake were closed in 2019. River Pond area of Tuttle Creek State Park, located below dam, remained open. State Park data indicated that 2019 visits were 26 percent lower in 2019, compared to 2018, due to flooding conditions, mostly driven by decreases in the summer and fall months. For example, in June 2019, state park visitation was 67% percent lower than visitation in June 2018 (USACE and KDWP 2018-2019). Annual state park fees, including entrance fees, camping fees, and other revenues were \$617,000 in 2019, down 18% compared to state park fees in 2018.

In 2019, Tuttle Creek Lake was above multi-purpose pool for over 160 days, with a max crest of 60 feet above top of multi-purpose pool (USACE 2020). Both USACE and KDWP recreation areas at Tuttle Creek Lake were closed for the 2019 season and experienced severe damage. In the USACE recreation areas, there were four public use areas impacted, including 12 structures, two campgrounds, one beach, three boat ramps, one lift station, 29 electrical panels, and various other infrastructure was submerged. Three miles of roads, eight parking areas, and 2.5 miles of trails were submerged and required restoration and repair. The USACE flood damages to recreation infrastructure have been estimated to be \$1.3 million; total USACE damages at Tuttle Creek Lake, including damages to roads and parking areas, were estimated to be \$4 million (FY2019 dollars) (USACE 2020 Federal Budget Supplemental Spreadsheet).

The state parks at Tuttle Creek Lake incurred damages to docks, fish cleaning stations, and campsites, and required considerable removal of debris. The state flood damages to recreation infrastructure have been estimated to be \$242,000; total state damages at Tuttle Creek Lake, including damages to roads and parking areas, were estimated to be \$551,000 (FY2019 dollars) (Personal Communication with Steve Adams, 2020). After the 2019 flood event, two USACE campgrounds remained closed for the 2020 season, and these repairs are estimated to be completed in 2023. It will take years to recover from the 2019 flood, with some areas permanently closed.

In 2019, the "Country Stampede", a popular country music festival event, which has historically been held at River Pond below the dam at Tuttle Creek Lake, was relocated to Topeka due to flooding threats; subsequently, organizers of the event announced the venue move was to be permanent.

In 2012, drought conditions impacted levels at reservoirs and lakes across Kansas, including at Tuttle Creek Lake, impacting access to boating and other recreational activities (NOAA 2012; KWO 2013). However, impacts to recreation at Tuttle Creek Lake during the 2012 season were minimal as boat ramps remained accessible through the peak recreation season; the drought didn't cause ramp closings until after Labor Day weekend.

Harmful algal blooms haven't historically been an issue at Tuttle Creek Lake, however in 2021 there was a HAB watch in July and a warning in October. Both advisories were lifted within a week and only occurred at River Pond below the reservoir (End of Summer Summary, 2021).

3.4.1.1. Critical Lake Elevations for Recreation

Lake elevations are an important factor for water- and shore-based recreation at Tuttle Creek Lake. Working with the USACE lake staff and KDWP fisheries experts, critical lake elevations for recreation were identified at Tuttle Creek Lake as well as the corresponding impacts to visitation shown in Tables 61 and 62 below. These lake elevations are used in the recreation modeling effort to assess the impacts to visitation and economic benefits under FWOP conditions. Other important water surface elevations for the reservoirs are part of the lake level management plans, which specify lake elevations to support fish and wildlife. It is important to note that water surface elevation and depth of water are not equivalent. For example, the water surface elevation may rise five feet above the multi-purpose pool, but if 10 feet of sediment were to accrue at the bottom of the lake, then the lake's depth would decrease five feet. This is not accounted for quantitatively in the model, but it is important to consider it qualitatively when assessing impacts of water surface elevation and reservoir depth to recreation, especially boating and fishing.

Lake Elevations/	<1,070 ft	1,070-1,072 ft	1,072-1,080; multi-purpose pool is 1,075 ft	1,080-1,086 ft	1,086-1,105 ft	>1,105 ft
Visitation Impacts	There is no boating access; campers and other shore-based visitors are also affected.	25% of boating access is available; all other recreation largely unaffected. 1,070 is the minimum elevation for boat ramp access	No issues.	80% of boating access is available; all other uses are largely unaffected.	No boat ramps accessible; 75% of lake shore access closed.	All recreation is closed at the lake.
Quality of Recreation Effects	Exposed lakeshores adversely affect aesthetic qualities for visitors.	Safety becomes an issue for remaining boaters; underwater hazards begin to surface (e.g., rocks, debris, and obstacles in shallow water).	No impacts	Increased debris can present a hazard to boaters.	Safety becomes an issue for remaining visitors; flooded roadways present hazard to drivers.	Generally, all recreation is closed at the lake

Table 61. Critical Lake Elevations for Recreation at Tuttle Creek Reservoir¹

¹ The information in this table was developed with input from USACE and KDWP staff familiar with Tuttle Creek Lake. Lake Elevations are in NGVD 1929

Table 62. Percent of Reservoir Impacted by Critical Lake Elevation Thresholds

Lake Elevations/	<1,070 ft	1,070-1,072 ft	1,072-1,080; multi-purpose pool is 1,075 ft	1,080-1,086 ft	1,086-1,105 ft	>1,105 ft
Water-based Visitor Impacts	100%	75%	0%	20%	100%	100%
Shore-based Visitor Impacts	50%	0%	0%	0%	75%	100%

¹ The information in this table was developed with input from USACE and KDWP staff familiar with Tuttle Creek Lake. Lake Elevations are in NGVD 1929

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3.4.2. Future Without Project Conditions

This section considers the impact of future conditions on recreation, including sediment, water surface elevations, water quality and fishery conditions. The first few sections describe how sediment and water surface elevations will change under the four FWOP scenarios, and how these changes will impact visitation and economic benefits. The FWOP scenarios that include navigation releases are considered in Section 3.4.2.4. A qualitative evaluation of how changes in water quality and fishery conditions will affect recreation in the future is provided in Sections 3.4.2.5 and 3.4.2.6, respectively.

3.4.2.1. Changes in Sediment and Water Surface Elevations

This section considers three precipitation conditions and their impacts on visitation and economic benefits under the FWOP scenarios, including typical precipitation periods, drought periods, and high water or flooding periods. To identify the drought and flood years, average annual elevations were analyzed across the period of record. Three years were chosen to evaluate flood conditions, with average annual elevations at Tuttle Creek Lake above 1,098 feet NGVD 29, while two years were chosen to evaluate drought conditions, with average annual elevations below 1,067 feet NGVD 29. See Tables 61 and 62 for a description of impacts to recreation at different lake elevation thresholds.

Drought years include:

- 2044 (1940)
- 2060 (1956)

Flood years include:

- 2055 (1951)
- 2097 (1993)
- 2123 (2019)

Typical years include all other years.

3.4.2.1.1. Sediment Conditions

Sedimentation has and will continue to impact recreation at Tuttle Creek Lake, more so than any other lake in the basin. To date, three parks (Swede Creek, Garrison, and Baldwin) and numerous private/community docks and ramps have been closed as a direct impact of sedimentation, reducing lake access, and affecting residents and visitors. Two state parks, Fancy Creek and Randolph, have converted to primarily land-based recreation with the loss of boat ramps and a marina. Consistent with these observations, Corps data shows that only 6% and 7% of activities at Fancy Creek State Park and Randolph State Park, respectively, are water-based activities (i.e., boating, angling, or swimming).

As sediment continues to accumulate and the delta extends southward, the size of the multipurpose pool and the lake's recreational opportunities will continue to decrease. Figure 20, 21, 22, and 23 show the depths of Tuttle Creek Lake at multi-purpose pool in 2024, 2049 (25 years), 2074 (50 years), and 2124 (100 years). Figure 19 shows the depths at all of those years on one map. Small scale dredging of boat ramps and small coves has occurred along with park closures. Recreation areas have been converted to land-based recreation, and recreational development has been concentrated towards the southern portion of the lake area.

During typical precipitation conditions (at multi-purpose pool), the Corps sediment modeling indicates that boat ramps at Cedar Ridge State Park, Stockdale Park, Tuttle Creek Cove Park, and Carnahan Park would provide boating access to the lake in 2024. In 2049, the boat ramps and water access at Carnahan

Park and Stockdale Park would not be available as these areas would have considerable silt and sediment (or new lands created) or be too shallow for boating access. The recreation areas adjacent to the lake that would remain boat-ramp accessible would be Tuttle Creek Cove Park and Cedar Ridge State Park as well as the areas below the dam. In 2074 (50 years) and 2124, the Corps sediment modeling indicates that the marina and boat ramps would no longer be accessible on Tuttle Creek Lake, and the coves at Tuttle Creek Cove Park and Cedar Ridge State Park would largely be silted in. It appears that camp sites would be further from the water at these recreation areas as well.

During drought conditions, the effects of sediment deposition on recreational access become more severe as decreasing water surface elevations reduce the depths of the lake (see description on water surface elevations). In addition, boating safety concerns and obstacles are more pronounced with a shallower lake. During flooding conditions, sediment deposition affects the operations of the reservoir and in general increases water surface elevations as sediment fills the pool over time.


Figure 19. Multi-purpose Pool Elevation Contours – Past and Future



Figure 20. Tuttle Creek Reservoir Baseline Depths – 2024



Figure 21. Tuttle Creek Reservoir Future Depths with Projected Sedimentations – 2049 (25 Years)



Figure 22. Tuttle Creek Reservoir Future Depths with Projected Sedimentations – 2074 (50 Years)



Figure 23. Tuttle Creek Reservoir Future Depths with Projected Sedimentations – 2124 (100 Years)

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3.4.2.1.2. Water Surface Elevations

Water surface elevations at Tuttle Creek Lake are generally higher in the future with increasing sediment deposition in the lake. Table 63 summarizes the average lake elevations over the 100-year period of analysis under the four FWOP scenarios. On average, the lake is slightly less than a foot higher in 2049 and 2074 compared to 2024 conditions. In 2124, Tuttle Creek Lake is just under one foot higher than under the FWOP 2024 scenarios without navigation releases. Additional information is provided in Appendix B, the Water Management Appendix.

FWOP Scenario	Average Water Surface Elevations ft	Change in Average Water Surface Elevations from 2024
2024	1,078.0	-
2049	1,078.2	+0.23 (0.02%)
2074	1,078.4	+0.38 (0.04%)
2124	1,078.9	+0.88 (0.08%)

Table 63. Average	e Water Surf	ace Elevations	at Tuttle	Creek Reservoir
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Note: The top of the multi-purpose pool is 1,075 feet. Elevations are in NGVD 1929 Represents average across the period of record.

As previously described, drought conditions with lower water surface elevations and increasing sediment deposition at Tuttle Creek Lake in the future cause additional water-access and safety issues due to shallower pools and exposed bottom areas. There are two notable drought periods over the 100-period of analysis: 2044 (translates to past year of 1940) 2060 and 2061 (translates to past years of 1956 and 1957). There are three notable high water or flood years over the 100-year period of analysis: 2055 (translates to past year of 1951), 2097 (translates to past year of 1993), 2123 (translates to past year of 2019).

Under both flooding and drought conditions, on average, pools levels are higher in FWOP 2049, 2074, and 2124 conditions than experienced under FWOP 2024 conditions (Table 64). During drought conditions, on average in 2044, 2060, and 2061, pool levels in 25 years (2049) are approximately half a foot higher, while in 50 and 100 years, pool levels are between 0.8 feet to 1.6 feet higher than under 2024 FWOP conditions.

_	-	-
FWOP Scenario	Change in Average Water Surface Elevations from 2024 During Drought Years	Change in Average Water Surface Elevations from 2024 During Flood Years
2049	+0.43	+0.65
2074	+0.81	+0.07
2124	+1.61	+0.52

Table 64. Average Annual Water Surface Elevations During Drought and Flood Years

Note: The top of the multi-purpose pool is 1,075 feet. . Lake Elevations are in NGVD 1929

During the 2060-2061 drought period, under the FWOP 2024 scenarios, the pool is between 1,070 and 1,058 feet (from five to 17 feet lower than multi-purpose pool) between July 2060 and until June 2061 when it rises back to multi-purpose pool level. Future sediment deposition in 2049 and 2074 increases pool elevations up to two feet higher compared to FWOP 2024 scenarios during this drought period.

Drought conditions, similar to those experienced in the mid-1950s, result in relatively lower water surface elevations (between five and 17 feet below multi-purpose pool) for almost two years between 2059 and 2061, which could result in severe implications for recreation with current and future sediment conditions. See Section 3.4.2.2.1 for more detail on drought impacts to recreation visitation.

In 2024, the Corps sediment modeling indicates that boat ramps at Cedar Ridge State Park, Stockdale Park, Tuttle Creek Cove Park, and Carnahan Park would provide boating access to the lake in 2024 under typical precipitation conditions. In 25 years (FWOP 2049 scenario), recreation areas adjacent to the lake that would remain boat-ramp accessible will be Tuttle Creek, Cove Park, Cedar Ridge State Park, and the areas below the dam. Because water surface elevations would be considerably lower during drought periods than the multi-purpose pool elevation, all recreation areas may not be accessible to boats and may increase safety concerns across the lake compared to typical precipitation water surface elevations.

Under three notable high water or flood years over the 100-year period of analysis, as shown in Table 64, on average, water surface elevations are less than a foot higher under the FWOP 2049, 2074, and 2124 conditions compared to FWOP 2024, although on any given point over the flood years, the difference between 2123 water surface elevations and FWOP 2024 and FWOP 2049, FWOP 2074 water surface elevations can be up to eight feet higher. However, at peak water surface elevations in these years, the difference among the water surface elevations under all FWOP scenarios is minimal.

The worst flood year in terms of visitation was in 2123 (2019) when, during the year, water surface elevations were above elevation 1,105 ft (see threshold table in existing conditions section) between 288 and 291 days under all of the FWOP scenarios. In general, Tuttle Creek Lake is closed to visitation when water surface elevations are 1,105 feet NGVD 29.

3.4.2.2. Changes in Visitation

This section describes how changes and lake elevations and sediment conditions can potentially impact visitation. Sediment deposition and relatively lower and higher water surface elevations have direct impacts on water-based visitors (boaters, swimmers, anglers) and indirect impacts to shore-based visitors for the recreation areas adjacent to the lake (termed lake-elevation affected recreation areas). In the following sections, we describe the potential impacts to visitation compared to all visitation during typical conditions at the lake-elevation affected recreation areas under the baseline year, 2018. In 2018, 362,100 people visited recreation areas that are potentially impacted by lake elevations, which includes dispersed recreation. We also compare the impacted visitation to 2018 baseline visitation at all locations at Tuttle Creek Lake. In 2018, visitation across Tuttle Creek Lake was estimated to be 1,016,600.

In most cases across the Kansas River Basin, visitation across the lakes has been fairly stable over the past 20 years. In some cases, such as at Tuttle Creek Lake, visitation at the state parks has been decreasing (see section 3.4.1.3). It is likely that decreasing visitation is tied to previous and ongoing visitation impacts from sediment accumulation, rendering boat ramps inaccessible and turning reservoir conditions into river conditions in the recreation areas in the upper part of the lake. For this reason, we assume that the sediment modeling is capturing these decreasing visitation trends in the future.

3.4.2.2.1. Typical Precipitation Conditions

Sediment is the main driver of recreation impacts across the lake, although drought and flood conditions can exacerbate these impacts to recreation further decreasing access and quality of recreation at the lake. Due to the considerable impacts to water-based visitors from sediment deposition impacting access, a sediment map-based assessment was conducted for typical precipitation conditions.

In 2024, there are four recreation areas adjacent to Tuttle Creek Lake with water-based access and accessible boat ramps: Cedar Ridge State Park, Stockdale Park, Tuttle Creek Cove Park, and Carnahan Park (Table 65 below). In 2049, water-based access would be considerably reduced at Stockdale and Carnahan parks due to the accumulation of sediment in these "arms" of the lake (Figure 21); visitors and recreators could shift from these recreational areas to Tuttle Creek Cove Park and Cedar Ridge State Park, although the boat ramps on the lake currently support high numbers of boaters and boating anglers,

indicating limited additional capacity to accommodate additional boaters. An estimated 48,700 waterbased recreators (Carnahan and Stockdale) would be affected, and if it is assumed that all water- and shore-based visitation at these two recreation areas shift to another lake or opt not to recreate, 95,500 visitors would be impacted (see Table 65 below). These visitors represent from five to nine percent of visitors under baseline conditions (2018) at Tuttle Creek Lake. If these recreation areas were converted to accommodate only shore-based activities, perhaps with construction of trails or OHV areas, a new mix of visitors would be anticipated, although it is difficult to ascertain how visitation would ultimately be impacted.

Starting in 2074 (50 years) and continuing through 2124 (100 years), an estimated 123,900 (water-based) and 318,300 (both water- and shore-based) visitors annually could be impacted by reduced lake access (see Table 65 below). According to the Corps' sediment modeling, no boat ramps would be accessible on Tuttle Creek Lake. It is possible that some of the visitors engaged in water-based activities could shift to shore-based activities; however, it is likely that some of the visitors, both water- and shore-based visitors, to these four recreation areas would choose to visit other lakes or opt not to recreate because water access is no longer available, shorelines are covered in silt and sediment, and other adverse aesthetic impacts could also occur (e.g., odors). Affected parks and recreation areas on Tuttle Creek Lake are shown in Table 65. A reduction in annual visitation of 123,900 and 318,300 represents a reduction of 12 and 31 percent of 2018 baseline visitation, respectively.

3.4.2.2.1. Drought Conditions

During drought conditions, notably the period between August 2059 and June 2061, consistent with the historic drought of the mid-1950s, water surface elevations are considerably lower than the top of multipurpose pool across all FWOP scenarios (from five to 17 feet lower than multi-purpose pool during this period) and considerably below thresholds important for recreation. In drought conditions, consistent with mid-1950s water conditions, all water-based access at recreation areas at the lake would be impacted under all FWOP scenarios. In addition, modeling shows periods of low to no storage at Tuttle Creek during extreme drought conditions. This would have multi-year impacts as the fishery would be impacted, recreation infrastructure (e.g., boat ramps) may require repairs and modifications, visitation would be severely impacted, and revenue sources to maintain the lakes would decrease.

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Tuttle Creek Lake	Visits	Affected by Sediment Deposition in the Future	Percent Water Based	Percent Shore Based	FWOP Year When Water-Based Access is Severely Impacted
CARNAHAN PARK	14,100	Y	56.9%	43.1%	2049
CEDAR RIDGE	154,900	Y	28.9%	71.1%	2074
FANCY CREEK STATE PARK*	74,100	N	6.5%	93.5%	Prior to 2024
OBSERVATION POINT	21,400	N	17.6%	82.4%	Below the dam
ORV AREA	12,700	Ν	2.0%	98.0%	Located away from the lake
OUTLET	146,700	N	17.6%	82.4%	Below the dam
RANDOLPH STATE PARK*	18,600	N	7.5%	92.5%	Prior to 2024
RIVER POND STATE PARK	362,500	N	54.0%	46.0%	Below the dam
SPILLWAY CYCLE AREA	14,900	N	17.6%	82.4%	Below the dam
STOCKDALE	81,400	Y	50.0%	50.0%	2049
TUTTLE CREEK COVE PARK	67,900	Y	44.8%	55.2%	2074
Dispersed Use (USACE)**	43,800	Y/N	4.3%	95.7%	N/A
KDWP Wildlife area/dispersed use	3,600	N/A	N/A	N/A	N/A
Total	1,016,600	N/A	N/A	N/A	N/A
Total visitation at recreation areas affected by sediment in the lake (2049)	95,500	N/A	48,700	46,800	N/A
Total visitation at recreation areas affected by sediment in the lake (2074 and 2124) (excludes dispersed recreation)	318,300	N/A	123,900	194,400	N/A
Total visitation at recreation areas affected by water surface elevations (includes water and shore-based recreation and dispersed recreation)	362,100	N/A	125,800	236,300	N/A

Table 65. Tuttle Creek Reservoir 2018 Visitation Impacted During Typical Precipitation Conditions

* These areas have already converted to mostly land based recreation, not included in totals at bottom of table

**There is some dispersed recreation that involved boating; for the sediment evaluation, it is assumed that dispersed boaters and shore-based visitors could adjust or modify their behaviors with increasing sediment deposition; the visitors are not included in the second to last row in the table.

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The impacts to visitation during an extreme drought under all FWOP scenarios would be similar to the visitation impacts described under the FWOP 2074 (50 years) and 2124 (100 years) scenarios above under typical precipitation conditions, when boat ramps and the marina would not be accessible. An estimated 123,900 (water-based) and 318,300 (both water- and shore-based) visitors could be impacted by reduced lake access during these types of conditions; a reduction in visitation of 123,900 and 318,300 represents between 12 and 31 percent of 2018 visitation. Dispersed visitors could also be impacted by considerably reduced lake elevations as they would not be able to access areas adjacent to the lake to visit; these visitors account for 43,800 visits in 2018. Additional visitation could also be affected in areas that are not directly impacted by changes in lake elevations, such as in the recreation areas below the dam, although these impacts are not included in the estimates. For example, if lower releases impact fishing conditions on fishing success below the dam, there could be additional impacts to recreation and reductions in visitation not captured in the abovementioned estimates.

Modeling of water surface elevations and critical lake elevations for recreation in the FWOP 2024 scenario show that in 2060 (modeled after 1956 drought conditions), visitation at the recreation areas that could potentially be impacted by changes in lake elevations would be 146,600, a reduction of approximately 215,000 visitors from 2018 baseline conditions at lake-elevation affected recreation areas. The year 2044 (modeled after 1940 conditions) would have similar impacts to visitation.

3.4.2.2.2. Flood Conditions

Within the 100-year period of analysis, considerable flood events would occur under the FWOP in 2055 (modeled after 1951 conditions), 2097 (1993), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation in FWOP 2024 conditions show considerable impacts to visitation at the recreation areas adjacent to the lake in these years (Table 66). A reduction in visitation at recreation areas impacted by changes in water surface elevations at Tuttle Creek Lake in 2123, consistent with conditions experienced in 2019, indicates a potential visitation decrease of 32 percent compared to baseline conditions at Tuttle Creek Lake (2018). In comparison, state park data indicated that 2019 visits were 26 percent lower than in 2018, due to flooding conditions, mostly driven by decreases in visitation in the summer and fall months. Annual state park fees, highly correlated with visitation, were \$617,000 in 2019, down 18 percent compared to state park fees in 2018.

There could also be impacts to visitation at the recreation areas below the dam (e.g., River Pond State Park, Spillway Cycle Area, Outlet, Observation Point) with potentially higher releases from the dam and localized flooding below the dam and safety closures could occur; these impacts are not captured in these figures. Table 66 below shows how flood conditions affect recreation in areas affected by changes in lake elevations by comparing visitation at those areas in modeled "flood years" (2055, 2097, and 2123) to baseline conditions (2018).

Flooding Years	FWOP 2024 Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	FWOP 2024 Reduction in Visitation at Lake-Elevation Affected Areas from Baseline Visitation	Percent Decrease in Visitation at Lake-Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018) at All Recreation Areas
Visitation under Baseline Conditions (2018)	362,100	-	362,100	1,016,600
2055	126,200	-235,900	-65%	-23%
2097	65,200	-296,900	-82%	-29%
2123	37,300	-324,800	-90%	-32%

	Table 66. Annual	I Changes in Visitat	on Associated with	n Modeled Flood	Events, FWOP 2024
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In FWOP 2074 and 2124 scenarios, as described above, all water-based visitation at recreation areas affected by changes in lake elevations would be inaccessible due to sediment deposition in the lake. With flooding conditions, potentially more shore-based visitors could be impacted in the recreation areas around the lake as flooding can impact roads, trails and campgrounds with slightly higher reservoir elevations under future conditions compared to the FWOP 2024 scenarios. If all water- and shore-based visitors in the recreation areas adjacent to the lake are impacted during flooding conditions, 362,100 visitors would be affected, representing 35% of visitation under baseline conditions at Tuttle Creek Lake (2018).

Under the FWOP 2049 scenarios, only two recreation areas adjacent to the lake remain accessible during typical water surface elevations: Cedar Ridge State Park, and Tuttle Creek Cove Park. Comparing water surface elevations impacts on visitation during the three flood events, water surface elevations are up to one foot higher under the FWOP 2049 conditions compared to FWOP 2024. These slightly higher surface elevations under FWOP 2049 scenario leads to more frequent closures of facilities (water surface elevations above 1,105 feet NGVD 29) and small decreases in visitation compared to FWOP 2024 visitation during these flood events, as shown in Table 67. The most pronounced impacts would occur in the 2123 event, leading to an additional reduction in visitation of 6,100 compared to FWOP 2024 visitation.

Flooding Years	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Change in Visitation Compared to FWOP 2024	Percent Change Compared to FWOP 2024	Percent Change at FWOP 2049 Compared to Baseline Visitation at Tuttle Creek Lake (2018)
Visitation under Baseline Conditions (2018)	362,100	-	-	362,100	1,016,600
2055	125,000	-237,100	-1,200	<-1%	-23%
2097	63,200	-298,900	-2,000	<-1%	-29%
2123	31,200	-330,900	-6,100	-2%	-33%

Table 07 Observes in		A		Elecal Essente		0040
Table 67 Changes in	VISITATION	Associated v	vith wodeled	FIGOD EVENTS	FVVOP	2049
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3.4.2.3. Changes in Economic Benefits

3.4.2.3.1. Consumer Surplus

Consumer surplus values are measured through the Corps' Unit Day Value (UDV) approach further described in Section 2.0. This section describes how changes and lake elevations and sediment conditions can potentially impact recreation consumer surplus values. Sediment deposition and relatively lower and higher water surface elevations have direct impacts on water-based visitors (boaters, swimmers, anglers) and indirect impacts to shore-based visitors for the recreation areas adjacent to the lake (termed lake-elevation affected recreation areas). In the following sections, we describe the potential impacts to consumer surplus values compared to all recreation values during typical conditions at the lake-elevation affected recreation areas under the baseline year, 2018. Visitation during baseline conditions at the recreation areas that are potentially impacted by lake elevations (including dispersed recreation) support an estimated \$3.3 million in consumer surplus value. We also compare the impacted consumer surplus values to baseline visitation and values (2018) at all locations at Tuttle Creek Lake. In 2018, visitation across Tuttle Creek Lake supported approximately \$9.6 million in consumer surplus values.⁷

Typical Precipitation Conditions

Reductions in visitation at Tuttle Creek Lake due to sediment deposition would result in lower consumer surplus values as described in this section. In 2024, there are four recreation areas adjacent to Tuttle Creek Lake with water-based access and accessible boat ramps at: Cedar Ridge State Park, Stockdale Park, Tuttle Creek Cove Park, and Carnahan Park (Table 65). In 2049, water-based access would be considerably reduced at Stockdale and Carnahan parks due to the accumulation of sediment in these "arms" of the lake (Figure 21). As described above, it is possible that boaters and anglers at these affected areas could shift to Cedar Ridge State Park and Tuttle Creek Cove Park if capacity is available, move to other lakes in the region, or choose not to recreate at all. If all water-based visitors no longer came to Tuttle creek Lake due to these two recreation areas being unavailable, there would be an annual loss of \$436,600 in consumer surplus values. Shore-based visitors at Stockdale and Carnahan Parks contribute an estimated \$415,900 in consumer surplus value, and it is likely a portion of these visitors would also be impacted by 2049 sediment conditions by the reduced ability to view and recreate near the lake or by decreased aesthetic qualities (Table 68 below).

In 2074 (50 years) and 2124 (100 years), according to the Corps' sediment modeling, the marina and all boat ramps will no longer be accessible on Tuttle Creek Lake. An estimated 123,900 (water-based) and 318,300 (both water- and shore-based) visitors could be impacted by reduced lake access at the four recreation areas. It is possible that some of the visitors engaged in water-based activities could shift to shore-based activities; however, it is likely that some of the visitors, both water- and shore-based visitors, to these four recreation areas would choose to visit other lakes or opt not to recreate because water access is no longer available, shorelines are covered in silt and sediment, and other adverse aesthetic impacts are occurring (e.g., odors, reduced fishing success). The water-based visitors at these four recreation areas contribute \$1.1 million in consumer surplus, while all visitors at these four recreation areas contribute \$2.9 million in consumer surplus (Table 68).

A reduction in all water-based visitors (\$1.1 million) at these four recreation areas represents 12% of all visitation and value at Tuttle Creek Lake under baseline conditions, while if all visitors at these four

⁷ Consumer surplus values are estimated with recreation visitor day and the Corps' UDV approach. In the modeling effort, visits were converted to recreation visitor days to apply the UDV using an estimate of average number of days per trip at the Kansas City District lakes to estimate consumer surplus. In this appendix, visitation is presented and described for consistency, and not recreation visitor days.

recreation areas Were impacted, 30% of baseline visitation and value would be impacted. Dispersed visitors engage in sightseeing, boating, wildlife viewing, and other activities, although their use is not tied to one recreation area. These visitors may also be impacted by increasing sediment deposition, decreasing water-based access, declining fishing success, and aesthetic changes at the lake (see last two rows of Table 68).

Table 68. Tuttle Creek Reservoir Visitation and Consumer Surplus Impacted by Sedimer	۱t
Deposition During Typical Precipitation Conditions Under FWOP Scenarios	

Tuttle Creek Lake	Total Visitation and CS Values	Water Based Visitation and CS Values	Shore Based Visitation and CS Values				
Baseline Visitation (2018)	1,016,600	283,800	732,800				
Baseline Consumer Surplus Values (2018)	\$9,600,000	\$2,680,000	\$6,920,000				
Potential Losses in FW							
Potential Losses in Visitation in 2049	95,500	48,700	46,800				
Potential Losses in Consumer Surplus in 2049	\$852,500	\$436,600	\$415,900				
Potential Losses in FWOP 2074 and 2124 (includes 2049) ²							
Potential Losses in Visitation in 2074, 2124 (includes 2049)	318,300	123,900	194,400				
Potential Losses in Consumer Surplus in 2074, 2124 (includes 2049)	\$2,851,500	\$1,123,100	\$1,728,300				
Potential Losses in FW	OP 2074 and 2124 (inc	cludes 2049 and dispersed recre	eation)				
Potential Losses in Visitation in 2074, 2124 (includes 2049 and dispersed recreation)	362,100	125,800	236,300				
Potential Losses in Consumer Surplus in 2074, 2124 (includes 2049 and dispersed recreation)	\$3,277,000	\$1,130,000	\$2,147,000				

¹ Recreation areas impacted by sediment deposition in 2049 include Carnahan and Stockdale parks.

² Recreation areas impacted by sediment deposition in 2074 and 2124 include Carnahan and Stockdale parks and Cedar Ridge and Tuttle Creek Cove parks.

*Consumer Surplus is expressed in FY22\$

Drought Conditions

The impacts to visitation during an extreme drought would impact all water-based visitation at lakeelevation impacted recreation areas under all FWOP scenarios, a loss of \$1.1 million in consumer surplus values (Table 68). Drought conditions can also affect shore-based visitors if the lake shore is further away from camping and picnic area, or if shallow pools pose unappealing features or conditions (e.g., odors, swampy areas, mosquitoes, etc.) With elevations below 1,070 feet NGVD 29, an estimated 50 percent of shore-based visitors could be impacted (see Section 3.4.1.4), with an additional potential loss of between \$864,000 and \$1.1 million in consumer surplus values annually (Table 68).

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled droughts years of 2044 (modeled after 1940 conditions) and 2060 (modeled after 1956 conditions), reduced visitation would translate to a potential loss in consumer surplus values during drought conditions of approximately \$1.9 million annually (Table 69). There would be similar impacts under FWOP 2049, 2074, and 2124 conditions. These reductions in visitation in the recreation areas impacted by changes in lake elevations represent an annual decrease of 20 percent compared to 2018 baseline conditions.

Table 69. Ar	nual Visitatior	n and Consumer	[·] Surplus C	hanges /	Associated [•]	with Drought E	Events,
FWOP 2024			-	-		_	

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake-Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake- Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus at Lake-Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus (2018)
Baseline condition (2018)	362,100	-	\$3.3 million	\$3.3 million	\$9.6 million
2044	140,900	-221,200	-\$1.9 million	-58%	-20%
2060	146,600	-215,500	-\$1.9 million	-58%	-20%

* Consumer Surplus is expressed in FY22\$

Flood Conditions

Within the 100-year period of analysis, considerable flood events would occur in 2055 (modeled after 1951 conditions), 2097 (1993), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss in consumer surplus values during flood conditions of between \$2.1 and \$2.9 million in consumer surplus values, representing a decrease between 22 and 30 percent of total consumer surplus at Tuttle Creek Lake under baseline conditions (Table 70 below). There could also be impacts to visitation at the recreation areas below the dam (e.g., River Pond State Park, Spillway Cycle Area, Outlet, Observation Point) with potentially higher releases from the dam and localized flooding below the dam, although these impacts were not modeled.

Table 70. Annual Visitation and Consumer Surplus Changes Associated with Modeled FloodEvents, FWOP 2024

Flood Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake- Elevation Affected Areas	Percent Decrease in Visitation at Lake- Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018)
Baseline condition (2018)	362,100	-	\$3.3 million	\$3.3 million	\$9.6 million
2055	126,200	-235,900	-\$2.1 million	-64%	-22%
2097	65,200	-296,900	-\$2.6 million	-79%	-27%
2123	37,300	-324,800	-\$2.9 million	-88%	-30%

*Consumer Surplus is expressed in FY22\$

In FWOP 2074 and 2124 scenarios, as described above, all water-based visitation would be inaccessible due to sediment deposition in the lake. With flooding conditions, potentially more shore-based visitors could be impacted in the recreation areas around the lake as flooding can impact roads, trails and campgrounds. If all water- and shore-based visitors (lake elevations above 1,105 feet NGVD 29) in the lake elevation affected recreation areas were to choose another lake or not recreate at all, 362,100 visitors could be affected, with a loss of \$3.3 million in consumer surplus values (Table 70). In the modeled years of 2097 and 2123, average elevations were above the 1,105 feet NGVD 29 threshold at Tuttle Creek Lake.

Under the FWOP 2049 scenarios, as described above, only two recreation areas remain accessible adjacent to the lake due to sediment deposition: Cedar Ridge State Park, and Tuttle Creek Cove Park. Under FWOP 2049 conditions, water surface elevations are up to two feet higher compared to FWOP 2024 conditions during modeled years of 2055 and 2097 and up to three feet higher in 2123. These higher water surface elevations under FWOP 2049 scenario leads to more frequent closures and small decreases in consumer surplus values compared to FWOP 2024 consumer surplus during these flood events.

3.4.2.3.2. Regional Economic Benefits

Regional economic impacts are estimated through the Corp's RECONS model and further described in Section 2. This section describes how changes to lake elevations and sediment conditions can potentially impact regional economic benefits (jobs and income) to adjacent communities. Visitors spend their money in local communities, providing regional economic benefits in these communities. Sediment deposition and relatively lower and higher water surface elevations have direct impacts on water-based visitors (boaters, swimmers, anglers) and indirect impacts to shore-based visitors for the recreation areas adjacent to the lake (termed lake-elevation affected recreation areas). In the following sections, we describe the potential impacts to regional economic benefits from reduced visitation compared to regional economic benefits supported under baseline conditions in 2018. Consistent with visitation in 2018, 1,016,600 visitors support 278 jobs and \$9.1 million in labor income in the local economy under baseline conditions. In the recreation areas potentially affected by changes in lake elevations under baseline conditions, 362,100 visitors support 104 jobs and \$3.4 million in labor income.

Typical Precipitation Conditions

Reductions in visitation at Tuttle Creek Lake due to sediment deposition would result in lower regional economic benefits to adjacent communities as described in this section. In 2024, there are four recreation

areas adjacent to Tuttle Creek Lake with water-based access and accessible boat ramps at: Cedar Ridge State Park, Stockdale Park, Tuttle Creek Cove Park, and Carnahan Park (Table 65). In 2049, water-based access would be considerably reduced at Stockdale and Carnahan parks due to the accumulation of sediment in these "arms" of the lake (Figure 21). As described above, it is possible that boaters and anglers at these affected areas could shift to Cedar Ridge State Park and Tuttle Creek Cove Park if capacity is available, move to other lakes in the region, or choose not to recreate at all. If all water-based visitors no longer came to Tuttle Creek Lake due to these two recreation areas being unavailable, there would be an annual loss of 15 jobs and \$500,000 in labor income. Shore-based visitors at Stockdale and Carnahan Parks contribute an estimated 13 annual jobs and \$400,000 in labor income, and it is likely some of these visitors would be impacted by 2049 sediment conditions and no longer come to the Lake because of the reduced ability to view and recreate near the lake and decreased aesthetic qualities (Table 71).

In 2074 (50 years) and 2124 (100 years), according to the Corps' sediment modeling, the marina and all boat ramps would no longer be accessible on Tuttle Creek Lake. An estimated 123,900 (water-based) and 318,300 (both water- and shore-based) visitors could be impacted by reduced lake access at the four recreation areas. It is possible that some of the visitors engaged in water-based activities could shift to shore-based activities; however, it is likely that some of the visitors, both water- and shore-based visitors, to these four recreation areas would choose to visit other lakes or opt not to recreate because water access is no longer available, shorelines are covered in silt and sediment, and other adverse aesthetic impacts could also occur (e.g., odors, reduced fishing success).

The water-based visitors at these four recreation areas support 38 jobs and \$1.4 million in labor income, annually, while all visitors at these four recreation areas contribute 93 jobs and \$3.0 million in labor income (Table 71. A reduction in all water-based visitors at these four recreation areas accounts for 19 percent of all jobs supported by visitation at Tuttle Creek Lake annually under baseline conditions, while if all visitors at these four recreation areas were to no longer visit the lake, there would be a reduction of 33 percent of jobs supported by visitation at the lake compared to baseline conditions. Dispersed visitors engage in sightseeing, boating, wildlife viewing, and other activities, although their use is not tied to one recreation area. These visitors may also be impacted by increasing sediment deposition, decreasing waterbased access, declining fishing success, and aesthetic changes at the lake (see last two rows of Table 71). Due to the long-term sediment deposition in Tuttle Creek Lake, annual losses in jobs and income in the local economy would not be temporary and would persist overtime.

Impacts	Visits	Jobs	Labor Income	Gross Regional Product	Economic Output	
Baseline Conditions (2018) really n	1.1 million	278	\$9.1 million	\$16.3 million	\$30.8 million	
2049 Visitor Impacts (Carnahan and Stockdale)						
Water-based Visitors	48,700	15	\$0.5 million	\$1.0 million	\$1.8 million	
Shore-based Visitors	46,800	13	\$0.4 million	\$0.7 million	\$1.4 million	
Water- and shore- based Visitors	95,500	27	\$0.9 million	\$1.7 million	\$3.2 million	
2074 and 2021 Visitor Impacts (Carnahan, Stockdale, Cedar Ridge, and Tuttle Creek Cove Park)						

Table 71. Tuttle Creek Reservoir	Visitation and Regional Economic Benefits Impacted During
Typical Precipitation Conditions	

Impacts	Visits	Jobs Labor Income		Gross Regional Product	Economic Output		
Water-based Visitors	123,900	38	\$1.4 million	\$2.5 million	\$4.5 million		
Shore-based Visitors	194,400	53	\$1.6 million	\$3.0 million	\$5.8 million		
Water- and shore- based Visitors	318,300	93	\$3.0 million	\$5.5 million	\$10.3 million		
2074 and 2021 Visit dispersed recreatio	2074 and 2021 Visitor Impacts (Carnahan, Stockdale, Cedar Ridge, and Tuttle Creek Cove Park and dispersed recreation)						
Water-based Visitors	125,800	39	\$1.4 million	\$2.5 million	\$4.6 million		
Shore-based Visitors	236,300	65	\$2.0 million	\$3.7 million	\$7.0 million		
Water- and shore- based Visitors	362,100	104	\$3.4 million	\$6.2 million	\$11.6 million		

*Labor income is expressed in FY22\$

Drought conditions

The impacts to visitation during an extreme drought would impact all water-based visitation at lakeelevation impacted recreation areas under all FWOP scenarios. If these visitors did not come to the Reservoir, there would be a loss in annual regional economic benefits of 39 jobs and \$1.4 million in labor income compared to baseline conditions (Table 71). Drought conditions can also affect shore-based visitors, and if 50 percent of shore-based visitors would no longer visit these recreation areas, an additional loss of approximately 33 jobs and \$1.0 million in labor income, annually (last set of rows in Table 71).

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled drought years of 2060 (modeled after 1956 conditions), reduced visitation would lead to a potential loss of 70 jobs and \$2.3 million during drought conditions under 2024 FWOP compared to baseline conditions (Table 72). There would be similar impacts under FWOP 2049, 2074, and 2124 conditions. These reductions in economic benefits impacted by changes in lake elevations represent a 25 percent decrease in jobs from total jobs supported from all visitor spending at Tuttle Creek Lake under baseline conditions (278 annual jobs). Droughts can also have lasting impacts to tourism business depending on the timing of the recovery and resiliency of the businesses, including the reservoir refilling, the re-establishment of the fishery, steps to mitigate losses in visitation, and the demand for recreation at the lake.

Table 72. Annual Visitation and Changes in Regional Economic Benefits Associated with I	Drought
Events, FWOP 2024	

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Jobs at Lake- Elevation Affected Areas	Reduction in Labor Income at Lake- Elevation Affected Areas	Percent Decrease in Jobs and Income from Baseline Conditions
Baseline condition (2018)	362,100	-	104	\$3.4 million	278 jobs;

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Jobs at Lake- Elevation Affected Areas	Reduction in Labor Income at Lake- Elevation Affected Areas	Percent Decrease in Jobs and Income from Baseline Conditions
					\$9.1 million in labor income
2044	140,900	-221,200	-72	-\$2.4 million	-26%
2060	146,600	-215,500	-70	-\$2.3 million	-25%

*Labor income is expressed in FY22\$

Flood Conditions

Within the 100-year period of analysis, considerable flood events would occur in 2055 (modeled after 1951 conditions), 2097 (1993), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss of 95 jobs and \$3.1 million in labor income, representing a decrease between 27 and 34 percent of total jobs supported by visitor spending at Tuttle Creek Lake under baseline conditions (Table 73). There could also be impacts to visitation at the recreation areas below the dam (e.g., River Pond State Park, Spillway Cycle Area, Outlet, Observation Point) with potentially higher releases from the dam and localized flooding below the dam, although these impacts were not modeled.

Table 73. Annual Visitation and	Changes in Regional Eco	nomic Benefits Associated wit	h Flood
Events, FWOP 2024			

Flood Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Jobs at Lake- Elevation Affected Areas	Reduction in Labor Income at Lake- Elevation Affected Areas	Percent Decrease in Jobs and Income from Baseline Conditions
Baseline condition (2018)	362,100	-	104	\$3.4 million	278 jobs; \$9.1 million in labor income
2055	126,200	-235,900	-74	-\$2.4 million	-27%
2097	65,200	-296,900	-89	-\$2.9 million	-32%
2123	37,300	-324,800	-95	-\$3.1 million	-34%

*Labor income is expressed in FY22\$

In FWOP 2074 and 2124 scenarios, which is very similar to the FWOP 2024 scenario, all water-based visitation would be inaccessible due to sediment deposition in the lake. With flooding conditions, potentially more shore-based visitors could be impacted in the recreation areas around the lake as flooding can impact roads, trails and campgrounds. If all water- and shore-based visitors in the lake-elevation affected recreation areas were to choose another lake to visit or not come to Tuttle Creek Lake, 362,100 visitors could be affected, with a potential loss of 104 jobs and \$3.4 million in labor income (Table 73).

Under the FWOP 2049 scenarios, also similar to the FWOP 2024 scenario, only two recreation areas remain accessible adjacent to the lake due to sediment deposition: Cedar Ridge State Park, and Tuttle Creek Cove Park. Under FWOP 2049 conditions, water surface elevations are up to two feet higher compared to FWOP 2024 conditions during modeled years of 2055 and 2097 and up to three feet higher in 2123. These higher water surface elevations under the FWOP 2049 scenario during flood years leads to more frequent closures and small decreases in regional economic benefits compared to FWOP 2024 conditions. The most pronounced impacts would occur in the 2123 event.

Damages, Revenues, and Fees to States

Visitation to Tuttle Creek Lake contributes considerable revenue to the state to maintain parks. Revenue is collected through park entrance fees, camping fees, hunting and fishing license revenues, concessionaire fees. In 2018, the state park revenues associated with Tuttle Creek Lake were \$755,958, second in the Kansas River watershed only to Clinton Lake.⁸ At Tuttle Creek Lake in 2019, these revenues were \$617,000, a reduction of 18% from 2018 revenues due to reduced visitation from flooding events.

Hunting and fishing license sales are also important for the state, bringing in \$31.2 million in 2018 across the state, although this data is not available by lake. In general, these revenues vary over time and are typically proportional to visitation at the lakes. As described in this section, sediment deposition, droughts, and flooding conditions can have considerable impacts on this visitation and therefore revenue sources for the state. The evaluation indicates that sediment deposition combined with drought conditions could result in an annual decrease of visitation up to 31 percent of baseline conditions (2018), while flooding impacts would have slightly larger impact, impacting up to 32 percent of visitation under baseline conditions. These impacts would continue to occur overtime when droughts or flooding occur, with their occurrences becoming more frequent with climate change.

During these extreme events, the state and USACE often incur costs to repair damages, conduct small scale dredging, and other actions to repair or maintain infrastructure. Therefore, the state has less revenues coming in, with increased expenses, often impacting state coffers for years.

Estimated costs for repairs of recreational infrastructure associated with damage from the 2019 flood at USACE-managed recreation areas of Tuttle Creek were \$1.3 million. The impacts at the KDWP state parks at Tuttle Creek Lake include damages to docks, fish cleaning stations, and campsites, as well as actions to remove debris at \$106,000. These damages are likely to continue to occur in the future with extreme events.

3.4.2.4. Navigation Releases

3.4.2.4.1. Typical Precipitation Conditions

The H&H modeling suggest that navigation releases during non-flood and non-drought years (all years across the 100-year period of analysis that have not been identified as drought (2044 and 2060) and flood years (2055, 2097, and 2123)) cause annual reservoir elevations to be approximately a half foot lower than FWOP 2024, 2049, and 2074 scenarios without navigation releases on average across the period of analysis. In FWOP 2124, there is no change in the average reservoir elevations between with and without navigation releases across the period of analysis for typical, non-drought and non-flood years.

Due to these lower pool elevations in the FWOP 2024, 2049, and 2074 scenarios with navigation releases, modeled visitation is on average three to 3.5 percent lower than the FWOP scenarios without navigation

⁸These fees and revenues, generally paid by visitors to federal and state governments, are included in the estimate of economic output in described in Section 3.4.1.2.3.

releases across all these typical precipitation years. These changes also have similar implications for consumer surplus values and regional economic effects. The effects of sediment deposition in the Lake causes severe impacts to recreation under the FWOP 2049, 2084, and 2124 scenarios, even under typical precipitation conditions, and lower reservoir elevations could worsen these impacts. Under the FWOP 2024 scenario with navigation releases, lower pool elevations in these typical precipitation years could result in reduced visitation on average of approximately 10,700 visitors, with an associated reduction in consumer surplus values of \$98,000 compared to the FWOP 2024 scenario without navigation releases. There would be small decreases in regional economic benefits as well.

3.4.2.4.2. Drought Conditions

In the two modeled drought years (2044 and 2060), average reservoir elevations under FWOP 2024 with navigation releases in these years are approximately 1.8 feet lower than reservoir elevations under FWOP 2024 without navigation releases. In FWOP 2049 and FWOP 2074, average reservoir elevations with navigation releases in these years are approximately one foot lower than reservoir elevations under FWOP 2024 without navigation releases. In FWOP 2124, there is no change in the average reservoir elevations between with and without navigation releases across the period of analysis for these two drought years.

The effects of combined drought conditions and sediment deposition in the Tuttle Creek Lake causes severe impacts under all FWOP scenarios. Under FWOP 2024 and 2049 navigation release scenarios, visitation is low at the lake due to the lower water levels during drought conditions; modeling indicates that during drought conditions, there could be an additional reduction of 1,800 and 800 visits, respectively, due to relatively lower reservoir elevations with these navigation releases compared to FWOP scenarios without the navigation release, with very small decreases in consumer surplus and regional economic benefits.

3.4.2.4.3. Flood Conditions

In the three modeled flood years (2055, 2097, and 2123), average reservoir elevations under all FWOP scenarios with navigation releases show very little change compared to the scenarios without navigation releases, resulting in less than a half percent change in visitation under FWOP scenarios with navigation releases and FWOP scenarios without navigation releases. The effect of navigation releases on consumer surplus values and regional economic benefits during flood conditions would be negligible.

3.4.2.5. Water Quality

All reservoirs in the Kansas River Watershed, including Tuttle Creek Lake, will likely experience increasing effects of aging. Future water quality within the Kansas River watershed lakes is dependent on multiple influencing factors, some of which are challenging to predict and/or estimate. It can be assumed that continued, and increasing fertilizer use, will continue to influence the water quality of runoff, groundwater, streams, and lakes. Approximately 40% of the total watershed area is classified as Grassland/Herbaceous and Pasture/Hay, much of which is used as rangeland/stock areas for livestock in the watershed. The Kansas Department of Agriculture (2021) publishes total numbers of livestock (cattle, sheep, hogs), and increasing trends in the numbers of animals that require feed and produce increased quantities of manure, indicate the potential for worsening water quality in downstream lakes.

Continued sediment loading will diminish storage capacity, deliver increased quantities of nutrients and pollutants, and compound effects of eutrophication. Continued and enhanced water quality impairment may be expected at Tuttle Creek Lake. Consistent with existing conditions, storm events generating high run-off volumes will continue to transport the majority of sediment and nutrient loads to Tuttle Creek Lake. Deposited and suspended sediments affect aquatic habitat and life, contributing to reduced abundance and diversity via smothered spawning sites, inhospitable macroinvertebrate habitat, increased

turbidity, reduced light availability, inhibited phytoplankton and macrophyte growth, diminished sight and filter-feeding, and water temperature effects.

The nutrients nitrogen and phosphorus are abundantly available throughout the Kansas River Watershed. A watershed-wide pattern of increasing in-lake total phosphorus concentrations suggests potential for continued eutrophication (high algal productivity) at Kansas River Watershed reservoirs. Phosphorus is often considered a nutrient that limits primary productivity (e.g., phytoplankton, aquatic plants), although nutrient limitation of phytoplankton growth is dependent on species and may vary depending on time and location. Too much phosphorus can cause increased growth of algae and aquatic plants, which can result in decreased levels of dissolved oxygen, a process called eutrophication. Observed decreasing total nitrogen to total phosphorus (TN:TP) ratios may indicate an enhanced opportunity for seasonal harmful algal bloom (HAB) – algal blooms that produce toxins detrimental to human and animal health – issues as some flourish under conditions with elevated phosphorus availability and water temperature. Based on 30 years of annual testing at Tuttle Creek Lake, total phosphorus at the dam has been increasing and can be anticipated to increase in the future as fertilizer use in agriculture increases. With increased levels of phosphorus could result in algal blooms in Tuttle Creek Lake, although a number of other factors also impact the development of HABs (e.g., the ability to keep water moving through the reservoir).

Due to their ability to possibly release toxins detrimental to human and animal health, along with their ability to destroy aquatic habitat and life, and their unsightliness, HABs have the potential to further decrease recreation in the future at Tuttle Creek Lake. With extreme HAB conditions, warnings are issued along with closures for public access. Persistent warnings can also deter visitors from coming to the lake. Although difficult to predict, turbid conditions at Tuttle Creek will likely continue to limit primary production, including HABs. Deteriorating water quality could eventually lead to increased prevalence of HABs in Tuttle Creek Lake with adverse impacts to visitors in the future.

Water residence times were estimated for Tuttle Creek Reservoir (Appendix G). A reduction in residence time results in less time for nutrient and sediment constituents to settle within reservoirs and then passing them downstream. Reservoirs with higher sedimentation rates that are losing large portions of their multipurpose pool have the largest decreases in residence time expected in the future. Perry Reservoir has a very high sedimentation rate expected over the next 100 years and is estimated to have a reduction in residence time of 67% under the FWOP 2124 scenario. There will likely be a seasonality to these reductions in residence time with greater reductions during the wetter periods and increases during the drier periods.

3.4.2.6. Angling and Sport Fishery

Sediment conditions will continue to have adverse impacts for the fishery at Tuttle Creek Reservoir. The loss of habitat and water volume due to sedimentation impact the lake's capacity to produce fish. Sedimentation will continue to occur and has the potential to dramatically reduce recreational use of the reservoir, especially for anglers, as only 25% of the original multipurpose pool is expected to remain in 50 years. Dredging can be used to clear sediment from boat ramps to improve access but can also be used to improve shoreline depth for bank anglers and to improve fish habitat, although these efforts have been minimally effective due to rapid sediment accumulation. The high cost of dredging will also likely limit these projects to select locations. The role of turbidity on the fishery will likely only increase as water volume continues to decrease.

An additional stressor was added to this system when the invasive zebra mussels was first documented in the lake in 2017. The potential negative effects of their presence has not yet been realized. As

sedimentation deposition occurs in the future, anglers' fishing success will continue to decrease, causing further stress on these uses at the lake. In addition to sedimentation reducing access to boat ramps and marinas, a further deterrence for anglers will be declining fish abundance and associated fishing success.

In addition, it is likely that dynamic water level events will continue to play a prominent role in determining sportfish densities. Emigration of fish during periods of elevated release rates will likely occur in the future similar to past events that will lead to periodic reductions in sportfish species and a potential need for additional stocking. Anglers are able to utilize some of the sportfish that regularly emigrate out of the lake. There is well developed angler access immediately below the dam at the outlet structure, at the River Pond which is a lake connected to the river below the dam, and at the low head dam Rocky Ford a mile downstream. There is potential for increasing these angling opportunities as there have been ongoing discussions on how public access can be increased in the undeveloped stretch of the Big Blue River downstream of Tuttle Creek Reservoir. These trends could indicate a shifting of reservoir angling to angling in the river reaches below the dam where future conditions for the fish are not as tenuous. However, as the reservoir fishery considerably declines in the future, angling below the dam may also be adversely impacted.

3.5. Kansas River Mainstem

3.5.1. Existing Conditions

The Kansas River mainstem runs for approximately 173 miles from Junction City to Kansas City, Kansas (Figure 24). The river spans 10 counties and the major cities of Manhattan, Topeka, Lawrence, and Kansas City. There are 19 access points along the river that allow for many types of recreational opportunities including boating, an increasingly popular activity on the Kansas River. A popular recreation area is the Kaw River State Park, consisting of 76 acres in west Topeka, Kansas.

The Kansas River mainstem was designated as a National Water Trail in 2012 by the National Park Service. It is the world's longest prairie river with outstanding scenic, recreational, historic, and natural characteristics. The Kansas River Water Trail is part of the National Park Service's National Water Trails System, which is a network of water trails open to the public to explore and enjoy. National Water Trails have been established to protect and restore America's rivers, shorelines, waterways, natural areas along waterways, and increase access to outdoor recreation on shorelines and waterways. The National Water Trails are a distinctive national network of exemplary water trails that are cooperatively supported and sustained (National Park Service, 2020).



Source: Friends of the KAW

Figure 24. Kansas River Recreation Areas

3.5.1.1. Recreational Activities and Visitation

Just north of Lawrence, Kansas the KAW River Trail is a National Recreation Trail. It consists of a 10mile walking and biking trail that follows the Kansas River atop the levee on the north side of the Kansas River. Common recreation activities along the Kansas River mainstem include sightseeing, boating, fishing, camping on sandbars, hiking, hunting, biking, and more. In recent years there has been an increase in boating activities such as kayaking, canoeing, and air boating on the river. Fishing is also very common along the Kansas River mainstem, both from the shore and from a boat. Some of the boating access points are also connected to river trails and parks that provide opportunities for sightseeing, hiking, biking, and other recreation activities. When the water is sufficiently low, camping on sandbars within the river channel is also a popular recreation activity.

The Lawrence Levee Trail is a popular river trail for hiking and biking. Located along the north bank of the Kansas River, the Lawrence Levee Trail runs along the top of the flood-control levee on the outskirts of Lawrence, Kansas. The trail offers views of nearby farmland and the river as well as the downtown area of Lawrence on the opposite bank. The trail provides access to Riverfront Park, which features a disc golf course, off-leash dog park, and a wildlife and native grass preserve. At the southeastern end of the trail, various hiking and mountain biking spur trails provide a diverse range of experiences closer to the Kansas River. It also provides the ability to launch kayaks or, if in the middle of a kayaking trip, pull kayaks out of the river to break for lunch or a drink.

Projects to add boating play areas, river drops, and other boating features, are currently underway in several locations along the Kansas River mainstem (Buehler, 2020). Boating safety concerns associated with the Topeka Water Plant Weir have prompted the construction of rock structures within the weir to improve water currents and flows. The improvements also include putting in a small whitewater channel for boaters and an environmentally friendly fish channel adjacent to the boating channel for spawning fish.

The City of Lawrence is considering a \$1.24 million project to repair holes in the weir, stabilize the riverbank south of the dam, and design potential recreational components and access points to the river. The key features of this type of project include drop and play areas for kayaking, fishing, shoreline access, and future opportunities for kayak rental and connections to the Lawrence downtown corridor.

Large, organized events draw many people to the river. There are seven such annual events that, in 2015, were attended by a total of 545 people (Kansas River Commercial Dredging Final Environmental Impact Statement, 2017). Annually, there are up to 1,500 people that attend these seven regular events on the Kansas River, including the Manhattan Little Apple Paddle and the Great Kaw Adventure Race, among others. In addition, there are 10 businesses that rent canoes and kayaks along the river, as well as host guided paddle trips and guided fishing trips. These businesses can collectively draw approximately 500 visitors on a summer weekend (KDWP, 2019). One of the organizations, Friends of the Kaw, provides many educational paddle trips for the public. Friends of the Kaw guided 234 participants in 2014 (Kansas River Commercial Dredging Final Environmental Impact Statement, 2017) and in 2018 guided close to 1,000 people on the Kansas River (Friends of the Kaw Annual Report, 2018).

The Kaw River State Park is a popular recreational area along the Kansas River Mainstem. In 2018, the Kaw River State Park hosted an estimated 42,013 visitors. As described earlier, during spring, summer, and fall months (approximately April through October), an additional estimated 2,000 boaters per month (500 per weekend) are estimated to use the Kansas River mainstem (KDWP, 2019). Although most of the use is by local day visitors, approximately 30% of the visitors are estimated to come from regions outside of the Kansas River area (Buehler, 2020). These recreators stay in local accommodations or camp along the river if conditions permit.

Boating use of the Kansas River mainstem has increased over the past decade, with considerable growth in the recent years (Buehler, 2020). Subsequently, local emergency services are experiencing an increasing need to help boaters who were not prepared for the river and are acquiring additional equipment to meet these demands. For example, the Johnson County Northwest Consolidated Fire Department and the Leavenworth County Rescue Department have bought new equipment such as airboats and inflatable rafts to assist with rescue operations.

3.5.1.2. Recent Effects of Drought, Flooding, and other Conditions that Affect Recreation

Flooding can result in large adverse effects to river recreation, especially boating and other water-based activities. Hunters, anglers, and campers often utilize the sandbars which are not available in the event of a flood. However, sightseeing along the river can increase as people come to view the flood and experience the power of the river.

Friends of the Kaw has provided some river flow recommendations for paddlers in the Kansas River Mainstem (Buehler, 2020). They recommend that novices refrain from paddling in the river if the flow is more than 5,000 cubic feet per second (cfs). Experts are advised against paddling in the river if the flow is more than 8,000 cfs as sandbars begin to disappear. By 11,000 cfs the sandbars are extremely scarce and at 13,000 cfs the sandbars are completely gone. During the 2019 floods, Friends of the Kaw were only able to take two boat trips in April and could not be on the river for the rest of the year due to the high water. These businesses and others that benefit from these trips, such as restaurants and retail establishments, experienced a decrease in revenue. If severe enough, floods can destroy boat ramps, although this did not happen in 2019.

CFS	<1,000	1,000-1,500	1,500-5,000	5,000-8,000	8,000-11,000	>11,000
Ranges						
% of	100	25	0	50	75	100
Water-						
Based						
Visitors						
Impacted						
Impacts	People find	Water quality	No impacts	Novice	Sandbars	Sandbars are
	it difficult to	can be		paddlers	become	mostly gone
	paddle the	impacted,		should refrain	scarce;	
	river as the	causing		from boating	paddling is	
	channel is	unpleasant		on the river	extremely	
	narrow	odors			difficult	

Table 74. River Flow Boating Access Thresholds

Just like with flooding, drought can also have adverse effects on recreation on the Kansas River. When the flow of the river is under 1,500 cfs, water quality can be impacted, causing unpleasant odors. Additionally, when the flow of the river is under 1,000 cfs people find it difficult to paddle the river, as the channel is narrow and people will end up walking most of the prairie-based sand river, with longer boating travel times and considerable effort.

Sand and gravel dredging along the Kansas River mainstem can be dangerous to boaters, particularly if dredgers are actively mining sand, because the cables that attach the dredge to the bank can be a hazard to boaters. Cables can be just under the surface of the water, above the surface of the water, or moving up and down near the surface of the water. The dredge operators are not always aware when boaters approach, which can be dangerous for boaters, especially when the water is moving fast, and/or is very noisy. Also, some fishermen like to fish at night when visibility is limited, and cables are likely not lowered/lifted for safety. There is concern that members of the public and even many seasoned boaters do not know that these cables exist, so their presence can be even more dangerous to these users of the river. Currently, there are seven dredging locations along the river. The dredge site in De Soto, Kansas experiences considerable recreational use, causing the greatest issues with boaters compared to the other six locations.

3.5.2. Future Without Project Conditions

This section considers the impact future conditions such as river flow rate (measured in cubic feet per second or cfs) and water quality have on recreation visitation and economic benefits. The first few sections describe how flows will change under the four FWOP scenarios, and how these changes will impact visitation and economic benefits. Unlike many of the reservoirs, sediment is not expected to influence recreation on the Kansas River Mainstem. Additionally, many of the reservoirs measures the impacts to water-based and shore-based recreators. For this section, only the impacts to water-based recreators on the river will be measured.

3.5.2.1. Changes in Flow

This section considers three precipitation conditions and their impacts on visitation and economic benefits under the FWOP scenarios, including typical precipitation periods, low flow (drought) periods, and high flow (flooding) periods. To identify the low flow and high flow years, average annual flows were analyzed across the period of record. Four years were chosen to evaluate high flow conditions, with average annual flows on the river above 11,000 cfs, while one year was chosen to evaluate low flow conditions, with average annual flows below 1,000 cfs. See Table 74 for a description of impacts to recreation at various flow access thresholds.

Drought years include:

• 2060 (1956)

Flood years include:

- 2055 (1951)
- 2077 (1973)
- 2097 (1993)
- 2123 (2019)

Typical precipitation years include all other years.

Average annual flows on the Kansas River Mainstem are expected to change depending on the amount of precipitation received. Additionally, while not directly influenced by sediment, flows are indirectly influenced by how much sediment accumulates in the nearby reservoirs, because that plays a large role in how much flow is released from the reservoirs into the mainstem. On average, river flows at the Topeka gage are higher in future FWOP scenarios. The impacts to flow under the different FWOP scenarios are shown in Table 75 below.

Table	75	Average	Annual	Flows	on	Kansas	River
Table	15.	Average	Amuai	110113	UII	Nansas	1/1/01

FWOP Scenario	Average Annual Flows (cfs)
2024	5,210
2049	5,230
2074	5,250
2124	5,280

Represents average across the period of record at the Topeka gage.

There is one low flow year over the period of analysis: 2060 (translates to past year of 1956). There are four high flow years over the period of analysis: 2055 (translates to past year of 1951), 2077 (1973), 2097 (1993), and 2123 (2019).

Table 76 below shows the average annual flows for those extreme precipitation years across all FWOP scenarios.

Table 76. Average	Annual Flows	During Extreme	Precipitation Years
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Extreme Precipitation Year	Average Annual Flow (cfs)	
2060	860	
2055	22,580	
2077	19,020	
2097	26,290	
2123	17,520	

Note: River flows on the Kansas River mainstem with no impacts to boating range from 1,500 cfs to 5,000 cfs (Table 74)

During the 2060 low flow period, under the FWOP 2024 scenarios, the riverine flow dips to a record low of 615 cfs, and for the year averages 860 cfs.

The worst modeled future flood year in terms of visitation was in 2097 (modeled after 1993 conditions) when, during the year, flows average 26,290 cfs (see threshold table in existing conditions section) under all of the FWOP scenarios. In July of 2097, the flow of the river rises to a record high of 153,000 cfs. In

general, the Kansas River becomes very difficult, if not impossible, to recreate on when flows are above 11,000 cfs.

3.5.2.2. Changes in Visitation

This section describes how changes in river flow can potentially impact visitation at the river. Impacts from sediment are not discussed as the Kansas River Mainstem flow is not directly influenced by sediment. In the following sections, the potential impacts to visitation under extreme precipitation conditions are described and compared to all visitation during typical precipitation conditions. In 2018, 19,700 people visited the river for water-based recreation purposes. This is the baseline visitation for a typical precipitation year.

3.5.2.2.1. Low Flow Conditions

During drought conditions, such as those experienced in 1956, flows are considerably lower across all FWOP scenarios than the normal flow range, as well as the thresholds important for recreation. During low flow conditions, all water-based access on the river would be impacted and/or limited under all FWOP scenarios. Modeling of flows in the FWOP 2024 scenario show that in 2060 (modeled after 1956 drought conditions), visitation could be decreased by 15,900 visitors from 2018 baseline conditions. Under FWOP 2049 and FWOP 2074, there are slight increases in visitation compared to FWOP 2024 conditions because of slightly higher river flows during the modeled year 2060. However, under FWOP 2124 scenario in the modeled year 2060, visitation would be 11 percent lower than FWOP 2024 conditions.

3.5.2.2.2. High Flow Conditions

Within the 100-year period of analysis, considerable flood events would occur under the FWOP in 2055 (modeled after 1951 conditions), 2077 (1973) 2097 (1993), and 2123 (2019). Modeling of flows across all FWOP scenarios shows considerable impacts to visitation during these high flow conditions. Under similar conditions to those experienced in 2019, the model indicates a potential visitation decrease of 84% compared to baseline conditions (2018).

Table 77 below shows how flood conditions under the 2024 FWOP affect recreation in areas affected by changes in lake elevations by comparing visitation at those areas in modeled "flood years" (2055, 2097, and 2123) to baseline conditions (2018). With flows as high as they were in 1993, modeled by the 2097 event, nearly all water-based recreation on the Kansas River would be eliminated. Visitation under all future FWOP scenarios would experience similar visitation impacts as those described under the FWOP 2024 scenario.

Flooding Years	Modeled Visitation at the Kansas River Mainstem During High Flow Conditions	Reduction in Visitation at the Kansas River Mainstem from Baseline Visitation	Percent Decrease in Visitation at the Kansas River Mainstem
Visitation under Baseline Conditions (2018)	19,700	-	-
2055	3,400	-16,300	-83%
2077	5,400	-14,300	-73%
2097	600	-19,100	-97%
2123	3,200	-16,500	-84%

Table 77. Annual Changes in Visitation Associated with Modeled High Flow Events, FWOP 2024

3.5.2.3. Changes in Economic Benefits

3.5.2.3.1. Consumer Surplus

Consumer surplus values are measured through the Corps' Unit Day Value (UDV) approach further described in Section 2.0. This section describes how changes in flows on the Kansas River can potentially impact recreation consumer surplus values. In the following sections, we describe the potential impacts to consumer surplus values compared to all recreation values during typical precipitation conditions on the river under the baseline year, 2018.

Typical Precipitation Conditions

Recreational visitation during baseline conditions at the on the river support an estimated \$191,900 annually in consumer surplus value.

Low Flow Conditions

The impacts to visitation during low flows (below 1,000 cfs) would impact all water-based visitation under all FWOP scenarios.

Modeling of river flows under FWOP 2024 conditions show that in the modeled low flow year of 2060 (modeled after 1956 conditions), reduced visitation of 15,900 would translate to a potential loss in consumer surplus values of approximately \$154,100 annually (Table 78). These reductions in visitation in the recreation areas impacted by changes in lake elevations represent an annual decrease of 81% compared to 2018 baseline conditions. In the modeled year 2060, consumer surplus under all future FWOP scenarios would experience similar impacts as those described under the FWOP 2024 scenario.

Table 78. Annual	Visitation and Consumer Surplus	Changes Associated wit	h Low Flow Even	ts,
FWOP 2024				

Drought Year	Modeled Boating Visitation on the Kansas River Mainstem	Reduction in Visitation at the Kansas River Mainstem from Baseline Visitation	Reduction in Consumer Surplus at the Kansas River Mainstem	Percent Decrease from Baseline Consumer Surplus at the Kansas River Mainstem
Baseline condition (2018)	19,700	-	\$191,100	-
2060	3,800	-15,900	-\$154,100	-81%

*Consumer Surplus is expressed in FY22\$

High Flow Conditions

Within the 100-year period of analysis, considerable high flow events would occur in 2055 (modeled after 1951 conditions), 2077 (1973), 2097 (1993), and 2123 (2019). Modeling of high flow events under FWOP 2024 conditions show that in modeled high flow years, reduced visitation would translate to a potential annual loss in consumer surplus values during flood conditions of between \$138,300 and \$186,000 in consumer surplus values, representing a decrease between 72 and 97% of total consumer surplus under baseline conditions (Table 79 below). In the modeled flood years, consumer surplus under all future FWOP scenarios would experience similar impacts as those described under the FWOP 2024 scenario.

Flood Year	Modeled Boating Visitation at the Kansas River Mainstem	Reduction in Visitation at the Kansas River Mainstem from Baseline Visitation	Reduction in Consumer Surplus at the Kansas River Mainstem	Percent Decrease from Baseline Consumer Surplus at the Kansas River Mainstem
Baseline condition (2018)	19,700	-	\$191,100	-
2055	3,400	-16,300	-\$157,600	-82%
2077	5,400	-14,300	-\$138,300	-72%
2097	600	-19,100	-\$185,000	-97%
2123	3,200	-16,500	-\$160,300	-84%

Table 79. Annual Visitation and Consumer Surplus Changes Associated with Modeled High Flor	w
Events, FWOP 2024 (Consumer Surplus is expressed in FY22\$)	

*Consumer Surplus is expressed in FY22\$

3.5.2.3.2. Regional Economic Benefits

Regional economic impacts are estimated through the Corp's RECONS model and further described in Section 2. This section describes how changes in visitation can potentially impact regional economic benefits (jobs and income) to adjacent communities. Visitors spend their money in local communities, providing regional economic benefits in these communities. In terms of the Kansas River, relatively lower and higher flows have direct impacts on water-based visitors (boaters, swimmers, anglers, etc.). In the following sections, we describe the potential impacts to regional economic benefits from reduced boating visitation compared to regional economic benefits supported under baseline conditions in 2018. Consistent with visitation in 2018, 19,700 visitors support 12 jobs and \$612,700 in labor income in the local economy under baseline conditions.

Low Flow Conditions

Modeling of flows under FWOP 2024 conditions show that in the modeled drought year of 2060 (translates to past year of 1956), reduced boating visitation would lead to a potential loss of 10 jobs and \$494,400 in labor income during low flow conditions under 2024 FWOP compared to baseline conditions (Table 80). Low flow periods often come with droughts which can also have lasting impacts to tourism business depending on the timing of the recovery and resiliency of the businesses, steps to mitigate losses in visitation, and the demand for recreation on the river. In the modeled 2060, regional economic benefits under all future FWOP scenarios would be similar as those described under the FWOP 2024 scenario.

Table 80. Annual Visitation and Changes in Regional Economic Benefits Associated with Low Flow Events, FWOP 2024 (Labor income is expressed in FY22\$)

Drought Year	Modeled Boating Visitation at the Kansas River Mainstem	Reduction in Visitation at the Kansas River Mainstem from Baseline Visitation	Reduction in Jobs at the Kansas River Mainstem	Reduction in Labor Income at the Kansas River Mainstem
Baseline condition (2018)	19,700	-	12	\$612,700
2060	3,800	-15,900	-10	-\$494,400

High Flow Conditions

Within the 100-year period of analysis, considerable flood events would occur in 2055 (modeled after 1951 conditions), 2077 (1973), 2097 (1993), and 2123 (2019). Modeling of flows under FWOP 2024 conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss of 6 to 12 jobs and \$444,000 and \$593,300 in labor income supported by boating visitor spending at and around the Kansas River under baseline conditions (Table 81). In the modeled flood years, regional economic benefits would be similar under all future FWOP scenarios as those described under the FWOP 2024 scenario.

Table 81. Annual Visitation and Changes in Regional Economic Benefits Associated with Flood Events, FWOP 2024 (Labor income is expressed in FY22\$)

Flood Year	Modeled Boating Visitation at the Kansas River Mainstem	Reduction in Visitation at the Kansas River Mainstem from Baseline Visitation	Reduction in Jobs at the Kansas River Mainstem	Reduction in Labor Income at the Kansas River Mainstem
Baseline condition (2018)	19,700	-	12	\$612,700
2055	3,400	-16,300	-10	-\$505,800
2077	5,400	-14,300	-6	-\$444,000
2097	600	-19,100	-12	-\$593,300
2123	3,200	-16,500	-10	-\$514,400

Results for the 2049, 2074, and 2124 FWOP scenarios are not significantly different than those of the FWOP 2024 scenario for all precipitation conditions and are thus not listed.

4.0. Smoky-Hill Saline Regional Planning Area

The Smoky Hill-Saline Regional Planning Area is in the central part of Kansas and includes two USACE reservoirs, Kanopolis and Wilson Lakes, and Cedar Bluff reservoir, operated by USBR. Figure 25 outlines the Smoky Hill-Saline Regional Planning Area and shows the location of the three reservoirs.



Figure 25. Smoky Hill-Saline Regional Planning Area

4.1. Kanopolis Lake

Kanopolis Lake is a dammed reservoir located on the Smoky Hill River in Ellsworth County, 31 miles southwest of Salina and a few miles southeast of the town of Kanopolis (Figure 26) (USACE Kanopolis Lake Map). It is part of the Smoky Hill-Saline Regional Planning Area.

4.1.1. Existing Conditions

4.1.1.1. Recreation Facilities & Visitation

Kansas Department of Wildlife, Parks and Tourism (KDWP) manages the Smoky Hill Wildlife Area, and Kanopolis State Park which is divided into Horsethief Area (eastern shore), and Langley Point Area (southern shore). The United States Corps of Engineers (USACE) manages Venango Park, Outlet Park, Riverside Park, Boldt Bluff, and Yankee Run. Below highlights the recreational infrastructure and opportunities available at Kanopolis Lake:

- Camping Sites
- Swimming Areas
- Trails (hiking, biking, horses, ATV, etc.)
- Hunting
- Fishing
- Marina
 - Boat Ramps

• Baseball Field



Figure 26. Kanopolis Reservoir Recreation Areas

Drought conditions in late 2012 and early 2013 precluded the use of any boat ramps on Kanopolis Reservoir. A temporary, custom ramp made of Marston mats was used to allow boat anglers access to the reservoir. Any decrease of elevation below conservation pool limits access to boats, and in many cases to shore anglers throughout much of the reservoir due to exposing mud flats. Projected sedimentation rates will further reduce access if new boat ramps are not built. Use by anglers will dramatically decline if boats are not able to access the reservoir.

Sport fish populations are likely to shift from pelagic predators (e.g., crappie, saugeye) to generalists (catfish species, common carp) if sedimentation rates continue as projected, due to overall surface acreage decreasing and habitat composition shifting entirely to sand and silt. Water clarity will likely continue to decline as sedimentation worsens and Common Carp and windy conditions keep benthic silt suspended within the water column. Turbid water conditions can dramatically impact productivity by reducing light penetration and limiting phytoplankton production to the far upper level of the water column. If Saugeye and crappie populations decline the angler use is likely to decline as anglers look for alternative locations with a more diverse fish population. Harmful algal blooms (HABs) are algae population explosions (blooms) that can release toxins that are dangerous to animals, including humans. Historically, HABs have not been an issue at Kanopolis Lake, however in 2020 there was a HAB watch.

According to combined USACE and KDWP data, visitation at the lake in 2018 was approximately 399,300 people. The state parks at Kanopolis Lake accounted for 64% of visitation in 2018, with most of



the use at South Shore (Langley Point) State Park. KDWP visitation data at the state parks indicate a relatively stable trend of visitation over the last 20 years as shown in Figure 27 below.

Figure 27. Kanopolis Reservoir Visitation, 2003-2022

Dispersed recreation, recreation that takes place outside of the established recreation areas, accounted for approximately 3% of visitation in 2018 (USACE VERS). In 2018, camping was the most popular recreational activity at Kanopolis Lake, accounting for 36% of visitation (USACE VERS 2018). Water-contact activities (swimming, etc.) were the second-most popular form of recreational activity, accounting for 16% of visitation. Hunting and wildlife viewing visits was the least popular recreational activity, accounting for an estimated one percent of total visitation.

4.1.1.2. Sport Fisheries

This section provides a summary of sport fishing at Kanopolis Lake. Additional information is provided in the Reservoir Fisheries Technical Report (see Appendix E). The 2013 Kansas Licensed Angler Survey listed Kanopolis Reservoir as the ninth-most preferred reservoir location to fish in Kansas. It is the 10thmost actually fished reservoir in the state. The proximity to Salina and McPherson makes this a popular destination for anglers inhabiting these urban centers in central Kansas. However, sedimentation has the potential to dramatically reduce use to the reservoir, especially for anglers.

4.1.1.3. Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

Kanopolis Reservoir is currently experiencing impacts to recreation from sedimentation. Sediment was dredged out of South Shore boat ramp area in 2010 and 2020. Currently, the boat ramp at Yankee Run is only accessible to smaller boats, such as jon boats and kayaks, because of shallow water conditions. At the conservation pool elevation of 1,463, access to the Horsethief boat ramp is lost, the Buzzard Bay boat ramp gets restricted, and marina access is limited. All of these restrictions and closures are due to sediment accumulation. Sediment also creates shallower water, creating worse and sometimes even
dangerous boating conditions. A lake elevation of 1,467.5 feet is ideal for recreation at current sediment levels, but that will change as more sediment accumulates and decreases depth while elevation remains constant.

In addition to affecting boating and water recreation, sedimentation at Kanopolis Lake affects fisheries conditions and angler opportunities. The lake has historically had a considerable crappie population; however, sediment deposition has led to a loss of structure or topographical components in the lake important to fish habitat that has affected this species and likely other fish species.

Kanopolis Reservoir experienced flooding during the spring of 2019, resulting in the closing of many recreation areas. Due to the spring flood event in the Missouri River basin, the lake was above top of multipurpose pool for over 60 days in 2019, with a max crest of 33 feet above top of multi-purpose pool (USACE 2020). Annual visitation was 24% lower in 2019 compared to annual visitation in 2018. The Venango recreation area closed in June and was also partially closed in July and August. Venango recreation area almost fully opened in September of 2019, with only severely damaged areas remaining closed.

Drought conditions decrease water surface elevation the longer they persist, and that can have negative effects on recreation at the lake. When water-based access is limited or no longer available due to low water, boaters, campers, and other visitors do not come to the lake. This impact can be especially profound because according to lake staff, boat ramps and electrical campsite availability seem to be the largest drivers for visitation (Ryan Williams, 4/6/2020). When the lake is low, all visitation is affected, even from visitors who would not participate in water-based activities. The region surrounding Kanopolis Lake suffered a drought during the mid-2000s as well as in 2012 and 2013. In 2006, the lake was so low that no boat ramps were usable.

4.1.1.4. Critical Lake Elevations for Recreation

Lake elevations are an important factor for water- and shore-based recreation at Kanopolis Lake. Working with the USACE lake staff and KDWP fisheries experts, critical lake elevations for recreation were identified at Kanopolis Lake as well as the corresponding impacts to visitation. These lake elevations are used in the recreation modeling effort to assess the impacts to visitation and economic benefits under FWOP conditions. Other important water surface elevations for the reservoirs are part of the lake level management plans, which specify lake elevations to support fish and wildlife. It is important to note that water surface elevation and depth of water are not equivalent. For example, the water surface elevation may rise five feet above the multi-purpose pool, but if 10 feet of sediment were to accrue at the bottom of the lake, then the lake's depth would decrease five feet. This is not accounted for quantitatively in the model, but it is important to consider it qualitatively when assessing impacts of water surface elevation and depth to recreation, especially boating and fishing. The critical lake elevations for recreation at Kanopolis Lake are in Table 82 and Table 83 below.

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Lake Elevations	<1,462 ft	1,462 – 1,466; multi-purpose pool is 1,463 ft	1,466 – 1,469 ft	1469 – 1,483 ft	1,483 – 1,495 ft	>1,495 ft
Visitation Impacts	Only one boat ramp is operable, and all other water-based access is no longer accessible, including beach.	Affects approximately 25% of boat ramps and access points become unusable; only smaller boats can access ramps.	Normal recreation conditions.	Affects a number of boat ramps, beach, some primitive campsites, and secondary access; approximately 25% of recreational facilities and areas are closed; Riverside Park remains operational.	Only a few recreation areas would remain open; electrical and primitive campsites mostly closed, and some park roads affected; approximately 75% of the recreation facilities and areas are closed. Riverside Park below the dam remains fully operational.	Restrooms and park roads are affected in all parks located on the main lake. Riverside Park below the dam remains fully operational.
Quality of Recreation Effects	Access to the water is one of the main drivers of visiting the lake. If you remove access whether it be a boat ramp, muddy shoreline that you can't access the water safely, or a beach that has a mud flat between the sand and water, it will impact recreation at the lake.	There are safety impacts; lower elevations and shallow water conditions affect the ability for first responders to reach boaters or visitors with response boats.	Normal recreation conditions.	Ramps and docks start to become unusable; Hazards become hidden by flood waters. Beaches start becoming unusable.	Ramps unusable due to hidden lanes, launching normal/deep draft boats becomes more difficult. Many hidden hazards.	Closed

Table 82. Critical Lake Elevations for Recreation at Kanopolis Reservoir¹

1 The information in this table was developed with input from USACE and KDWP staff familiar with Kanopolis Reservoir. Lake elevations in NGVD 1929.

Table 83. Percent of Reservoir Impacted by Critical Lake Elevation Thresholds

Lake Elevations	<1,462 ft	1,462 – 1,466; multi- purpose pool is 1,463 ft	1,466 – 1,469 ft	1469 – 1,483 ft	1,483 – 1,495 ft	>1,495 ft
Water-based Visitor Impacts	100%	75%	0%	20%	100%	100%
Shore-based Visitor Impacts	25%	0%	0%	20%	75%	100%

1 The information in this table was developed with input from USACE and KDWP staff familiar with Kanopolis Reservoir. Lake elevations in NGVD 1929

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4.1.2. Future Without Project Conditions

This section considers the impact of future conditions on recreation, including sediment, water surface elevations, water quality and fishery conditions. The first few sections describe how sediment and water surface elevations will change under the four FWOP scenarios, and how these changes will impact visitation and economic benefits. A qualitative evaluation of how changes in water quality and fishery conditions will affect recreation in the future is provided in Sections 4.1.2.6 and 4.1.2.7, respectively.

4.1.2.1. Changes in Sediment and Water Surface Elevations

This section considers three precipitation conditions and their impacts on visitation and economic benefits under the FWOP scenarios. These precipitation conditions are typical precipitation periods, drought periods, and high water or flooding periods. To identify the drought and flood years, average annual elevations were analyzed across the period of record. four years were chosen to evaluate flood conditions, with average annual elevations at Kanopolis Lake above 1,468 feet NGVD 29, while one year was chosen to evaluate drought conditions, with average annual elevations below 1,457 feet NGVD 29. See Tables 82 and 83 for a description of impacts to recreation at different lake elevation thresholds.

Drought years include:

• 2028 (1924)

Flood years include:

- 2055 (1951)
- 2077 (2073)
- 2097 (1993)
- 2123 (2019)

Typical years include all other years.

4.1.2.1.1. Sediment Conditions

Sedimentation has and will continue to impact recreation at Kanopolis Lake, more so than any other lake in the basin except for Tuttle Creek Lake. According to the Corps' sedimentation analysis, the boat ramps on the eastern side of the Lake, including those at Venango Park and East Shore State Park (Horsethief), will not be accessible in future years, starting in 2049. By 2049, at South Shore State Park, one boat ramp and the marina will no longer be accessible. By 2074, both boat ramps in the South Shore State Park and the marina will not be accessible. By 2074, the boat ramp at Yankee Run and along with the whole area in general will be fully silted in.

Dredging boat ramps can potentially mitigate/counter the effects of sedimentation and maintain access for boat ramps in the East and South Shore State Parks and in Venango Recreation Area. However, the enactment of this temporary measure is uncertain and dependent on funding availability. Without any management actions (e.g., dredging, reallocation), all boating and marina access to Kanopolis Lake would no longer be available in approximately 50 years, beginning in 2074. Lake managers have indicated that these conditions would result in a severe reduction in visitation if sediment on boat ramps and the marina are not mitigated. Not only would water-based visitors be affected, but also those visitors that come to view or be next to the lake. Boaters, anglers, and other water-contact activities at the recreational areas around the lake accounted for 124,000 visits in 2018, 31% of total visitation. Other shore-based visitors could also be affected, including special event attendees, campers, picnickers, and sightseers. Shore-based visitors at the recreation areas around the lake accounted for 249,000 or 62% of total visitation in 2018. Because the future is uncertain, sediment effects in years 50 to 100 could result in a reduction of visitation

at the recreation areas around the lake between 31% (water-based visitors – 124,000) to 62% (water-based visitors and half of shore-based visitors – 248,500) of 2018 visitation unless the adverse effects of sedimentation are mitigated. Maps of sediment accumulation at Kanopolis Lake are shown below in Figure 28 (2024), Figure 29 (2049), Figure 30 (2074), and Figure 31 (2124). The impacted visitation and years when access would be lost at the various recreation areas are summarized in Table 84 below.

Tuttle Creek Lake	Visits	Affected by Sediment Deposition in the Future	Percent Water Based	Percent Shore Based	FWOP Year When Water-Based Access is Severely Impacted
East Shore State Park	90,000	Y	24.3%	75.7%	2049
Info Center & Admin Area	3,500	N	22.1%	87.9%	Below Dam
Riverside Park	16,300	N	41.6%	58.4%	Below Dam
South Shore State Park	164,900	Y	30.8%	69.2%	2049
Venango Park	83,600	Y	42.5%	67.5%	2049
Yankee Run	18,600	Y	75.5%	24.5%	2049
Outlet Park	4,500	N	36.5%	63.5%	Below Dam
Dispersed Use (USACE)*	13,200	Y	90.3%	9.7%	2049
KDWP Wildlife Area	4,700	N	36.5%	63.5%	N/A
Total	399,300	N/A	206,000	193,300	N/A
Recreation areas affected by sediment in the lake (2049)	370,300	N/A	195,100	175,200	N/A

Table 84. 2018 Visitation Impacted by Sediment During Typical Precipitation Conditions



Figure 28. Kanopolis Reservoir Baseline Depths - 2024



Figure 29. Kanopolis Reservoir Future Depths with Projected Sedimentation – 2049 (25 Years)



Figure 30. Kanopolis Reservoir Future Depths with Projected Sedimentations – 2074 (50 Years)



Figure 31. Kanopolis Reservoir Future Depths with Projected Sedimentations – 2124 (100 Years)

4.1.2.1.2. Water Surface Elevations

Table 85 summarizes the average lake elevations over the 100-year period of analysis under the four FWOP scenarios. On average, the lake's average surface elevation is expected to increase very slightly over time. In 2124, Kanopolis Lake is expected to be just over one-tenth of a foot higher than the average surface elevation under the FWOP 2024 scenarios Additional information is provided in Appendix B, the Water Management Appendix.

FWOP Scenario	Average Water Surface Elevations (ft)	Change in Average Water Surface Elevations from 2024 (ft)
2024	1,463.36	-
2049	1,463.39	0.03
2074	1,463.39	0.03
2124	1,463.49	0.13

Table 85. Average Water Surface Elevations at Kanopolis Reservoir Across the Period of Record

Note: The top of the multi-purpose pool is 1,463 feet NGVD 29

Table 86. Average Annual Water	r Surface Elevations	During Drought and Flood Years
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FWOP Scenario	Change in Average Water Surface Elevations from 2024 During Drought Years	Change in Average Water Surface Elevations from 2024 During Flood Years
2049	-0.39	+0.15
2074	-0.68	+0.95
2124	-2.53	+2.63

Note: The top of the multi-purpose pool is 1,463 feet NGVD 29

During the 2028-2029 drought period, under the FWOP 2024 scenarios, the pool elevation drops from 1,463 feet NGVD 29 (multi-purpose pool level) to 1,453 feet NGVD 29 between May 2028 and October 2028 before gradually returning to multi-purpose pool level in December 2029. This could result in severe implications for recreation with current and future sediment conditions.

In 2024, the Corps sediment modeling indicates that boat ramps at East Shore State Park and South Shore State Park, would provide boating access to the lake in 2024 under typical precipitation conditions. In 25 years (FWOP 2049 scenario), no recreation areas adjacent to the lake will remain boat-ramp accessible. Because water surface elevations would be considerably lower during drought periods than the multi-purpose pool elevation, all recreation areas may not be accessible to boats and may increase safety concerns across the lake compared to typical precipitation water surface elevations.

Under the notable high water or flood years over the 100-year period of analysis, as shown in Table 86, on average, water surface elevations are up to 2.6 feet higher under the FWOP 2049, 2074, and 2124 conditions compared to FWOP 2024, although on any given point over the flood years, the difference between FWOP 2124 water surface elevations and FWOP water surface elevations can be up to 21 feet higher.

The worst flood year in terms of surface elevation was 2055, when, out of the whole year, water surface elevations were above elevation 1,495 feet NGVD 29 for 42 days for all FWOP scenarios. In general, Kanopolis Lake is closed to visitation when water surface elevations are 1,495 feet NGVD 29(see Tables 82 and 83).

4.1.2.2. Changes in Visitation

This section describes how changes in lake elevations and sediment conditions can potentially impact visitation. Changes in lake elevations and sediment have direct impacts on water-based visitors (boaters, swimmers, anglers) and indirect impacts to shore-based visitors for the recreation areas adjacent to the

lake (termed lake-elevation affected recreation areas). In the following sections, we describe the potential impacts to visitation compared to all visitation during typical conditions at the lake-elevation affected recreation areas under the baseline year, 2018. In 2018, 370,300 people visited recreation areas that are potentially impacted by changing lake elevations in the future; this figure includes dispersed recreators. We also compare the impacted visitation to 2018 baseline visitation at all locations at Kanopolis Lake. In 2018, visitation across Kanopolis Lake was estimated to be 399,300.

Trends in state park data over the past 16 years (2023-2022, excluding 2019-2021) indicate increasing visitation at approximately 0.7 percent as under baseline conditions. If past trends continue in the future, in approximately 75 years, visitation could be close to 1.5 times greater under baseline conditions. These future increases in visitation will have implications to consumer surplus and regional economic effects if these factors influencing visitation are not being captured in the modeling effort, with the potential for 150 percent of the impacts under FWOP 2124 scenario as estimated under this modeling effort.

4.1.2.2.1. Typical Precipitation Conditions

Sediment is the main driver of recreation impacts across the lake, although drought and flood conditions can exacerbate these impacts to recreation further decreasing access and quality of recreation at the lake. Due to the considerable impacts to water-based visitors from sediment deposition impacting access, a sediment map-based assessment was conducted for typical precipitation conditions.

In 2024, there are four recreation areas adjacent to Kanopolis Lake with water-based access and accessible boat ramps: East Shore State Park, South Shore State Park, Venango Park, and Yankee Run (Table 84). In 2049, water-based access would be considerably reduced at all five of the recreation areas and no boat ramps would be accessible due to the accumulation of sediment (Figures 28, 29, 30, and 31). An estimated 195,100 water-based recreators would be affected, and if it is assumed that all water- and shore-based visitation at these recreation areas shift to another lake or opt not to recreate, 370,300 visitors would be impacted (see Table 84). These visitors represent 49% and 93%, respectively, of visitors under baseline conditions (2018) at Kanopolis Lake. If these recreation areas were converted to accommodate only shore-based activities, perhaps with construction of trails or OHV areas, a new mix of visitors would be anticipated, although it is difficult to ascertain how visitation would ultimately be impacted.

4.1.2.2.2. Drought Conditions

During drought conditions, notably the year 2028, water surface elevations are considerably lower than the top of multipurpose pool across all FWOP scenarios (from 10 to 21 feet lower than multi-purpose pool during this period) and considerably below thresholds important for recreation (see Tables 82 and 83). During these conditions, all water-based access at recreation areas at the lake would be impacted under all FWOP scenarios.

The impacts to visitation during an extreme drought under all FWOP scenarios would be similar, though not as pronounced, to the visitation impacts due to sediment accumulation as described under the FWOP 2049, 2074, and 2124 scenarios above under typical precipitation conditions. An estimated 195,100 (water-based) and 370,300 (both water- and shore-based) visitors could be impacted by reduced lake access during these types of conditions. Additional visitation could also be affected in areas that are not directly impacted by changes in lake elevations, such as in the recreation areas below the dam, although these impacts are not included in the estimates. For example, if lower releases impact fishing conditions on fishing success below the dam, there could be additional impacts to recreation and reductions in visitation not captured in the abovementioned estimates.

Drought Years	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake-Elevation Affected Areas from Baseline Visitation	Percent Decrease in Visitation at Lake-Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018) at All Recreation Areas
Visitation under Baseline Conditions (2018)	370,300	-	-	399,300
2028	247,200	-123,100	-33%	-31%

Table 87. Annual Changes in Visitation Associated with Modeled Drought Events, FWOP 2024

Modeling of water surface elevations and critical lake elevations for recreation in the FWOP 2024 scenario show that in 2028 (modeled after 1924 drought conditions), visitation at the recreation areas that could potentially be impacted by changes in lake elevations would be 247,200, a reduction of approximately 123,100 visitors from 2018 baseline conditions at lake-elevation affected recreation areas (see Table 87).

4.1.2.2.3. Flood Conditions

Within the 100-year period of analysis, considerable flood events would occur under the FWOP in 2055 (modeled after 1951 conditions), 2077 (1973), 2097 (1993), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation in FWOP 2024 conditions show considerable impacts to visitation at the recreation areas adjacent to the lake in these years. A reduction in visitation at recreation areas impacted by changes in water surface elevations at Kanopolis Lake in 2123, consistent with conditions experienced in 2019, indicates a potential visitation decrease of 29 percent compared to baseline conditions at Kanopolis Lake (2018). In comparison, state park data indicated that 2019 visits were 17 percent lower than in 2018, due to flooding conditions, mostly driven by decreases in visitation in the summer and fall months.

There could also be impacts to visitation at the recreation areas below the dam with potentially higher releases from the dam and localized flooding below the dam and safety closures could occur; these impacts are not captured in these figures. Table 86 below shows how flood conditions affect recreation in areas affected by changes in lake elevations by comparing visitation at those areas in modeled "flood years" (2055, 2077, 2097, and 2123) to baseline conditions (2018).

Flooding Years	FWOP 2024 Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	FWOP 2024 Reduction in Visitation at Lake-Elevation Affected Areas from Baseline Visitation	Percent Decrease in Visitation at Lake-Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018) at All Recreation Areas
Baseline Conditions (2018)	370,300	-	-	399,300
2055	175,415	-194,885	-53%	-49%
2077	258,189	-112,111	-30%	-28%
2097	240,811	-129,489	-35%	-32%
2123	262,760	-107,540	-29%	-27%

Table OC	A	Chamman in	Vialtation	Acceleted	A N					2024
Table 86.	Annual	Changes in	visitation	Associated	with N	viodeled	FIOOD	Events.	FVVOP	ZUZ4
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During flooding conditions, up to roughly 50% of visitors at lake-elevation-affected areas could be impacted, and potentially even more shore-based visitors could be impacted in the recreation areas around

the lake as flooding can impact roads, trails and campgrounds with slightly higher reservoir elevations under future conditions compared to the FWOP 2024 scenarios.

4.1.2.3. Changes in Economic Benefits

4.1.2.3.1. Consumer Surplus

Consumer surplus values are measured through the Corps' Unit Day Value (UDV) approach further described in Section 2.0. This section describes how changes and lake elevations and sediment conditions can potentially impact recreation consumer surplus values. Sediment deposition, relatively lower water surface elevations, and relatively higher water surface elevations have direct impacts on water-based visitors (boaters, swimmers, anglers) and indirect impacts to shore-based visitors for the recreation areas adjacent to the lake (termed lake-elevation-affected recreation areas). In the following sections, we describe the potential impacts to consumer surplus values when visitation is impacted. Visitation during baseline conditions at the recreation areas that are potentially impacted by lake elevations (including dispersed recreation) support an estimated \$4.1 million in consumer surplus value. We also compare the impacted consumer surplus values to baseline visitation and values (2018) at all locations at Kanopolis Lake. In 2018, visitation across Kanopolis Lake supported approximately \$5.2 million in consumer surplus values.

Typical Precipitation Conditions

Reductions in visitation at Kanopolis Lake due to sediment deposition would result in lower consumer surplus values as described in this section. In 2049, water-based access would be considerably reduced at all parks adjacent to Kanopolis Lake due to the accumulation of sediment (Figure 29). An estimated 195,100 (water-based) and 370,300 (both water- and shore-based) visitors could be impacted by reduced lake access at the recreation areas. It is possible that some of the visitors engaged in water-based activities could shift to shore-based activities; however, it is likely that some of the visitors, both water- and shore-based visitors, to these recreation areas would choose to visit other lakes or opt not to recreate because water access is no longer available, shorelines are covered in silt and sediment, and other adverse aesthetic impacts are occurring (e.g., odors, reduced fishing success). If all water-based visitors no longer came to Kanopolis Lake, there would be an annual loss of \$2,235,100 in consumer surplus value, and it is likely a portion of these visitors would also be impacted by 2049 sediment conditions by the reduced ability to view and recreate near the lake or by decreased aesthetic qualities (Table 87 below).

During Typical Precip		Scenarios		
Kanopolis Lake	Total Visitation and CS Values	Water Based Visitation and CS Values	Shore Based Visitation and CS Values	
Baseline Visitation (2018)	399,300	206,000	193,300	
Baseline Consumer Surplus Values (2018)	\$5,200,000	\$2,682,700	\$2,517,300	
Potential Losses in FWOP 2049, 2074, and 2124				
Potential Losses in Visitation in 2049	-370,300	-195,100	-175,200	
Potential Losses in Consumer Surplus in 2049	-\$4,137,800	-\$2,235,100	-\$1,902,700	

 Table 87. Kanopolis Reservoir Visitation and Consumer Surplus Impacted by Sediment Deposition

 During Typical Precipitation Conditions Under FWOP Scenarios

*Consumer Surplus is expressed in FY22\$

Drought Conditions

The impacts to visitation during an extreme drought would impact all water-based visitation at lakeelevation impacted recreation areas under the FWOP 2024 scenarios, a loss of \$2.2 million in consumer surplus values. Drought conditions can also affect shore-based visitors if the lake shore is further away from camping and picnic area, or if shallow pools pose unappealing features or conditions (e.g., odors, swampy areas, mosquitoes, etc.) With elevations below 1,462 feet NGVD 29, an estimate 25% of shorebased visitors could also be impacted (see Tables 82 and 83), leading to a potential loss of \$0.5 million in addition to the loss of water-based consumer surplus for a total loss of \$2.7 million.

Table 88. Annual Visitation and Consumer Surplus Changes Associated with Drought Events,FWOP 2024

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake-Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake- Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus at Lake-Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus (2018)
Baseline condition (2018)	370,300	-	\$4.1 mil	-	\$5.2 mil
2028	247,200	-123,100	-\$2,700,000	-65%	-52%

*Consumer Surplus is expressed in FY22\$)

Flood Conditions

Within the 100-year period of analysis, considerable flood events would occur in 2055 (modeled after 1951 conditions), 2077 (1973), 2097 (1993), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss in consumer surplus values during flood conditions of between \$0.7 and \$1.8 million in consumer surplus values (Table 89 below). There could also be impacts to visitation at the recreation areas below the dam with potentially higher releases from the dam and localized flooding below the dam, although these impacts were not modeled.

Table 89. Annual Visitation and Consumer Surplus Changes Associated with Modeled Flood
Events, FWOP 2024 (Consumer Surplus is expressed in FY22\$))

Flood Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake- Elevation Affected Areas	Percent Decrease in Visitation at Lake- Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018)
Baseline condition (2018)	370,300	-	\$4.1 mil	-	\$5.2 mil
2055	175,415	-194,885	-\$1,800,000	-44%	-35%
2077	258,189	-112,111	-\$800,000	-19%	-15%
2097	240,811	-129,489	-\$1,000,000	-24%	-19%
2123	262,760	-107,540	-\$700,000	-17%	-13%

4.1.2.3.2. Regional Economic Benefits

Regional economic impacts are estimated through the Corp's RECONS model and further described in Section 2. This section describes how changes in lake elevations and sediment conditions can potentially impact regional economic benefits (jobs and income) for adjacent communities. Visitors spend their money in local communities, providing regional economic benefits in these communities. Sediment deposition and relatively lower and higher water surface elevations have direct impacts on water-based visitors (boaters, swimmers, anglers) and indirect impacts to shore-based visitors for the recreation areas adjacent to the lake (termed lake-elevation affected recreation areas). In the following sections, we describe the potential impacts to regional economic benefits from reduced visitation compared to regional economic benefits supported under baseline conditions in 2018. Consistent with visitation in 2018, 399,300 visitors support 104 jobs and \$3.9 million in labor income in the local economy under baseline conditions. In the recreation areas potentially affected by changes in lake elevations under baseline conditions, 370,300 visitors support 96 jobs and \$3.6 million in labor income.

Typical Precipitation Conditions

In 2049, according to the Corps' sediment modeling, the marina and all boat ramps will no longer be accessible on Kanopolis Lake. An estimated 195,100 (water-based) and 370,300 (both water- and shore-based) visitors could be impacted by reduced lake access at the recreation areas. It is possible that some of the visitors engaged in water-based activities could shift to shore-based activities; however, it is likely that some of the visitors, both water- and shore-based visitors, to these recreation areas would choose to visit other lakes or opt not to recreate because water access is no longer available, shorelines are covered in silt and sediment, and other adverse aesthetic impacts could also occur (e.g., odors, reduced fishing success). FWOP 2074 and 2124 impacts would be similar to those described for FWOP 2049.

Table 90. Kanopolis Reservoir Visitation and Regional Economic Benefits Impacted During Typical
Precipitation Conditions (Labor income is expressed in FY22\$)

Impacts	Visits	Jobs	Labor Income	Gross Regional Product	Economic Output
Baseline Conditions (2018)	399,300	104	\$3.9 million	\$6.8 million	\$13.9 million
FWOP 2049 Water- and shore-based Visitor Impacts	-370,300	-96	-\$3.6 million	-\$6.3 million	-\$12.9 million

Drought conditions

The impacts to visitation during an extreme drought would impact all water-based visitation at lakeelevation impacted recreation areas under all FWOP scenarios. If these visitors did not come to the Lake, there would be a loss in annual regional economic benefits of 44 jobs and \$1.8 million in labor income compared to baseline conditions. Droughts can also have lasting impacts to tourism business depending on the timing of the recovery and resiliency of the businesses, including the reservoir refilling, the reestablishment of the fishery, steps to mitigate losses in visitation, and the demand for recreation at the lake. The table below shows changes in regional economic benefits in years associated with drought events for the FWOP 2024 sediment scenario. The impacts would be more pronounced with the other sediment FWOP scenarios, as described in the above paragraph.

 Table 91. Annual Visitation and Changes in Regional Economic Benefits Associated with Drought

 Events, FWOP 2024 (Labor income is expressed in FY22\$)

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Jobs at Lake- Elevation Affected Areas	Reduction in Labor Income at Lake- Elevation Affected Areas	Percent Decrease in Jobs and Income from Baseline Conditions
Baseline condition (2018)	370,300	-	96	\$3.6 million	104 jobs; \$3.9 mil
2028	247,200	-123,100	-44	-\$1.8 million	-46%

Flood Conditions

Within the 100-year period of analysis, considerable flood events would occur in 2055 (modeled after 1951 conditions), 2077 (2073), 2097 (1993), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss of 59 jobs and \$2.2 million in labor income in 2055 (Table 92). There could also be impacts to visitation at the recreation areas below the dam with potentially higher releases from the dam and localized flooding below the dam, although these impacts were not modeled.

Table 92. Annual Visitation and Changes in Regional Economic Benefits Associated with Flood Events, FWOP 2024 (Labor income is expressed in FY22\$)

Flood Year	FWOP 2024 Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	FWOP 2024 Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	FWOP 2024 Reduction in Jobs at Lake- Elevation Affected Areas	FWOP 2024 Reduction in Labor Income at Lake- Elevation Affected Areas	Percent Decrease in Jobs and Income from Baseline Conditions
Baseline condition (2018)	373,300	-	96	\$3.6 million	104 jobs; \$3.9 mil
2055	175,415	-194,885	-59	-\$2.2 million	-56%
2077	258,189	-112,111	-36	-\$1.5 million	-38%
2097	240,811	-129,489	-39	-\$1.6 million	-41%
2123	262,760	-107,540	-35	-\$1.3 million	-33%

4.1.2.4. Damages, Revenues, and Fees to States

Visitation to Kanopolis Lake contributes considerable revenue to the state to maintain parks. Revenue is collected through park entrance fees, camping fees, hunting and fishing license revenues, concessionaire fees. In 2018, the revenues associated with Kanopolis Lake were \$261,111.9

Hunting and fishing license sales are also important for the state, bringing in \$31.2 million in 2018 across the state, although this data is not available by lake. In general, these revenues vary over time and are typically proportional to visitation at the lakes. As described in this section, sediment deposition, droughts, and flooding conditions can have considerable impacts on this visitation and therefore revenue

⁹These fees and revenues, generally paid by visitors to federal and state governments, are included in the estimate of economic output in described in Section 3.4.1.2.3.

sources for the state. The evaluation indicates that sediment deposition combined with drought conditions could result in an annual decrease of visitation up to 93 percent of baseline conditions (2018) if all visitation ceases at lake-elevation-affected recreation areas.

During these extreme events, the state and USACE often incur costs to repair damages, conduct small scale dredging, and other actions to repair or maintain infrastructure. Therefore, the state has less revenues coming in, with increased expenses, often impacting state coffers for years.

Estimated costs for repairs of recreational infrastructure associated with damage from the 2019 flood at USACE-managed recreation areas of Kanopolis Lake were \$204,000. The impacts at the KDWP state parks at Kanopolis Lake include damages to docks, fish cleaning stations, and campsites, as well as actions to remove debris are estimated at \$142,000 for a total recreational repair cost of \$346,000. These damages are likely to continue to occur in the future with extreme events.

4.1.2.5. Navigation Releases

There are no navigational releases at Kanopolis.

4.1.2.6. Water Quality

All reservoirs in the Kansas River Watershed, including Kanopolis Lake, will likely experience increasing effects of aging. Future water quality within the Kansas River watershed lakes is dependent on multiple influencing factors, some of which are challenging to predict and/or estimate. It can be assumed that continued, and increasing fertilizer use, will continue to influence the water quality of runoff, groundwater, streams, and lakes. Approximately 40% of the total watershed area is classified as Grassland/Herbaceous and Pasture/Hay, much of which is used as rangeland/stock areas for livestock in the watershed. The Kansas Department of Agriculture (2021) publishes total numbers of livestock (cattle, sheep, hogs), and increasing trends in the numbers of animals that require feed and produce increased quantities of manure, indicate the potential for worsening water quality in downstream lakes.

Continued sediment loading will diminish storage capacity, deliver increased quantities of nutrients and pollutants, and compound effects of eutrophication. Continued and enhanced water quality impairment may be expected at Kanopolis Lake. Consistent with existing conditions, storm events generating high run-off volumes will continue to transport the majority of sediment and nutrient loads to Kanopolis Lake. Deposited and suspended sediments affect aquatic habitat and life, contributing to reduced abundance and diversity via smothered spawning sites, inhospitable macroinvertebrate habitat, increased turbidity, reduced light availability, inhibited phytoplankton and macrophyte growth, diminished sight and filterfeeding, and water temperature effects.

The nutrients nitrogen and phosphorus are abundantly available throughout the Kansas River Watershed. A watershed-wide pattern of increasing in-lake total phosphorus concentrations suggests potential for continued eutrophication (high algal productivity) at Kansas River Watershed reservoirs. Phosphorus is often considered a nutrient that limits primary productivity (e.g., phytoplankton, aquatic plants), although nutrient limitation of phytoplankton growth is dependent on species and may vary depending on time and location. Too much phosphorus can cause increased growth of algae and aquatic plants, which can result in decreased levels of dissolved oxygen, a process called eutrophication. Observed decreasing total nitrogen to total phosphorus (TN:TP) ratios may indicate an enhanced opportunity for seasonal harmful algal bloom (HAB) – algal blooms that produce toxins detrimental to human and animal health – issues as some flourish under conditions with elevated phosphorus availability and water temperature. Based on 30 years of annual testing at Kanopolis Lake, total phosphorus at the dam has been increasing and can be anticipated to increase in the future as fertilizer use in agriculture increases. With increased levels of phosphorus in the future, storm events could result in algal blooms in Kanopolis Lake, although a number

of other factors also impact the development of HABs (e.g., the ability to keep water moving through the reservoir).

Due to their ability to possibly release toxins detrimental to human and animal health, along with their ability to destroy aquatic habitat and life, and their unsightliness, HABs have the potential to further decrease recreation in the future at Kanopolis Lake. With extreme HAB conditions, warnings are issued along with closures for public access. Persistent warnings can also deter visitors from coming to the lake. While historically not an issue, deteriorating water quality could eventually lead to increased prevalence of HABs in Kanopolis Lake with adverse impacts to visitors in the future.

Water residence times were estimated for Tuttle Creek Reservoir (Appendix G). A reduction in residence time results in less time for nutrient and sediment constituents to settle within reservoirs and then passing them downstream. Reservoirs with higher sedimentation rates that are losing large portions of their multipurpose pool have the largest decreases in residence time expected in the future. Perry Reservoir has a high sedimentation rate expected over the next 100 years and is estimated to have a reduction in residence time of 56% under the FWOP 2124 scenario. There will likely be a seasonality to these reductions in residence time with greater reductions during the wetter periods and increases during the drier periods.

4.1.2.7. Angling and Sport Fishery

Sediment conditions will continue to have adverse impacts for the fishery at Kanopolis Lake. The loss of habitat and water volume due to sedimentation impact the lake's capacity to produce fish. Sedimentation will continue to occur and has the potential to dramatically reduce recreational use of the reservoir, especially for anglers. Dredging can be used to clear sediment from boat ramps to improve access but can also be used to improve shoreline depth for bank anglers and to improve fish habitat, although these efforts have been minimally effective due to rapid sediment accumulation. The high effort and cost of dredging will also likely limit these projects to select locations. The role of turbidity on the fishery will likely only increase as water volume continues to decrease.

In addition, it is likely that dynamic water level events will continue to play a prominent role in determining sportfish densities. Emigration of fish during periods of elevated release rates will likely occur in the future similar to past events that will lead to periodic reductions in sportfish species and a potential need for additional stocking. Anglers are able to utilize some of the sportfish that regularly emigrate out of the lake. There are several factors that fisheries biologists need to continue to monitor in the future are impacts of reservoir aging on fish populations, flooding impacts, increased sedimentation, invasive species presence, and habitat fragmentation. The ability to use the best science available can lead to creating the best management practices to be able to maintain these fish populations in a constantly changing environment.

4.2. Wilson Reservoir

Wilson Reservoir and dam are operated by the USACE; the lake is in central Kansas, five miles north of Interstate 70 in the Saline river valley in both Russell and Lincoln counties (Figure 32). The reservoir is located 13.4 miles from the city of Lucas, Kansas, and about 25 miles from the city of Russell, Kansas. The USACE is authorized to operate both Wilson dam and reservoir for the purposes of flood control, recreation, fish and wildlife management and water quality improvement. It was authorized for irrigation storage, but it is not operated for that purpose.



Figure 32. Wilson Reservoir Recreation Areas

4.2.1. Existing Conditions

4.2.1.1. Recreation Facilities and Visitation

Wilson Reservoir is a 9,000-acre impoundment on the eastern border of Russell County Kansas on the Saline River. Wilson Reservoir has a variety of different recreation facilities and activities, including four parks managed by KDWP or the USACE. There are numerous recreational opportunities available at Wilson Reservoir:

- Recreation Areas and Parks
- Picnic Sites
- Camping Sites
- Playgrounds

- Swimming Areas
- Trails
- Boat Ramps
- Marina Slips

According to combined state park and USACE data, total visitation for 2018 was 461,300. The most popular areas are the state parks, including Hell Creek and Wilson State Parks (and Lake Wilson marina), accounting for 30% of visitation in 2018. Other popular recreation areas are USACE parks, Minooka Park and Lucas Park, both accounting for about 19% of total visitation in 2018.

Overnight camping and lodge stays accounted for 29% of activities at the lake, while picnicking and sight-seeing account for 10% and 7%, respectively. Water contact activities accounted for 20% of activities, while boating and angling accounted for 18% and six percent, respectively. Special events drew an estimated 4,600 visitors in 2018, one percent of all activities. iSportsman hunting data isn't currently available for Wilson Reservoir. The study team assumed that one percent of total visitation (4,612 visits with full compliance) is hunting within wildlife areas, based on averages from other lakes. Additionally, the assessment assumed that 21% of that figure (969) accounts for wildlife viewing based on a USFWS report that provides state-wide hunting, fishing, and wildlife viewing trips in Kansas³ (USFWS, 2017).

There are 26 miles of mountain biking trails in Wilson State Park, noted as an "epic" trail by the International Mountain Biking Association. An estimated 10 % of the visitation at Wilson State Park is associated with the mountain biking use. The area is also known for its bass fishing. According to lake staff in 2019 and 2020 up to 20-30% of anglers preferred to fish for bass.

4.2.1.2. Sport Fisheries

This section provides a summary of sport fishing at Wilson Reservoir. Additional information is provided in the Reservoir Fisheries Technical Report (see Appendix E). In terms of angling, the 2013 Kansas Licensed Angler Survey lists Wilson Reservoir as the number one preferred reservoir for fishing in the state, and it's also the number one most actually fished reservoir in the state. Angler preference for a specific species often varies based upon changes in species dominance that results from water fluctuation history and the impact of invasive species in the reservoir. Walleye and striped bass have ranked in the top four species preferred by anglers at Wilson Reservoir in the past four creel surveys. Largemouth bass have been ranked during the last two surveys. Since the last survey the number of anglers targeting bass has increased due to the rise in lake levels creating excellent habitat and an abundant bass population (Appendix E).

Due to its high salinity, Wilson Reservoir isn't used as a public water supply and hasn't experienced the elevation fluctuations of other western Kansas reservoirs. However, starting in 2006 the reservoir elevation began to decline and in April of 2016 hit a record low of 10.5 feet below conservation pool. This was remedied by heavy rains in June that added 5 feet of storage. More heavy storms in late August and early September filled the reservoir 2.5 feet beyond the conservation pool. This helped contribute to excellent sport fish populations from 2016 to 2019. Flooding in 2019 killed a high amount of grass and other shoreline vegetation. The reservoir doesn't have many issues with harmful algal blooms, although they have occurred irregularly (Appendix E).

Drought conditions and aquatic nuisance species (ANS) are the main stressors of sport fish populations within Wilson Reservoir. ANS alter the food webs in the reservoir, and their direct consumption of fish eggs creates recruitment issues for sport fish. Most management efforts have been directed at mitigating the negative effects of ANS. Dense annual stockings of striped bass was the main management technique for controlling white perch from 2000 to 2015. However, the drought from 2012 to 2016 caused poor health and slow growth of the striped bass population and efforts to improve their condition by lowering stocking rates and relaxing harvest regulations began in 2016. These efforts immediately improved conditions for striped bass but, unfortunately white perch numbers rebounded along with the lake levels in 2016 and their population has since increased dramatically. White perch provide an alternative forage for

sport fish at Wilson Reservoir but their extreme abundance, interspecific competition, and appetite for fish eggs creates more negative than positive results. Zebra mussel numbers seem to be positively correlated with inflow and typically remain low in abundance, but periods of high inflow experienced in 2016 and 2019 increased their numbers temporarily (Appendix E).

Drought conditions reduced visitation considerably from 2012-2016. Visitation improved starting in 2017, due in part to competitive bass fishing tournaments. Periods of drought and reduced surface elevation that allow vegetation to grow along exposed shorelines provide optimal habitat for largemouth bass when the reservoir refills. It is possible that high weekend use by bass anglers have precluded other user groups from visiting but that has not been documented. The distance from population centers might impact use in years of high gasoline prices. However, that might impact camping and general day use more than angling use and visitation (Appendix E).

4.2.1.3. Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

Sediment accumulation at Wilson Reservoir is low and has not caused any major impacts other than some local impacts to recreation in the past. Some shoreline erosion and deposition of silt has become an increasing concern. At Wilson Reservoir, the upper third of the lake is where the majority of sediment is deposited. The upper end of the lake, known as "Horseshoe Bend," acts as a natural depository for most sedimentation and debris. Several boat ramps in this region have dealt with local sedimentation and require periodic cleanouts.

The land surrounding the upstream portion of the lake is managed by KDWP. The lands consist of mostly agricultural leases that provide public access and hunting. A wildlife refuge is also located in this area. Lower elevations have been noted to provide better habitat for threatened and endangered species such as the whooping crane. However, high elevations can flood roadways and limit vehicular access.

The area suffered a drought during the mid-2000s as well as in 2012, 2013, 2014, and 2015. In 2006, the pool was very low from lack of streamflow from little to no precipitation. Low lake elevations rendered boat ramps unusable and decreased both water-based and shore-based recreation. The economy in the adjacent communities suffered in 2006 (USACE Project Manager, 2020). Localized dredging has been undertaken to maintain access to boat ramps during drought conditions.

Drought impacts hunting at Wilson Reservoir. An example of these impacts as cited by the lake's wildlife manager includes "On opening morning of upland bird season in November 2012, there were approximately 140 upland bird hunters at Wilson Wildlife Area. On opening morning of upland bird season in November 2013, there were 33 upland bird hunters on Wilson Wildlife Area. Likewise, there was a significant decline in pheasant and quail survey results on the wildlife area between 2012 and 2013. Deer hunter numbers remained stable regardless of drought conditions."

Because of the closures during drought conditions, visitation in 2012 and 2013 mostly occurred at the Spillway Ramp and the Hell Creek ramp. Visitation was reduced by approximately 30% during this time due to limited water access as only two out of nine ramps were accessible.

Due to the spring flood event in 2019 in the Missouri River basin, the reservoir was above multipurpose pool for more than 60 days, with a max crest of 11 feet above top of multi-purpose pool (USACE 2020). At the end of May in 2019, approximately half of the campsites were closed at Minooka Park and Lucas Park due to campsite flooding. The Minooka Park lift station was flooded, closing the main shower building and dump station. Water receded in late July and parts of the recreation areas and facilities were closed during August for repair construction to flooded sites. Additional flooding occurred during the last two weeks of August, damaging the repaired recreation infrastructure and access roads. The recreation areas were not fully repaired until June of 2020. Visitation overall decreased 27% in 2019, compared to

visitation in 2018. This was driven mostly by a 65% visitation decrease during the fall (Sep-Dec) (USACE and KDWP 2018-2019).

Flooding in 2019 also had a negative impact on hunting at both Kanopolis and Wilson Reservoirs. The wildlife manager was cited as stating "Receding flood waters resulted in poor habitat conditions on impacted acres and access issues. Some hunters that were planning fall hunting trips during spring/summer of 2019 opted to hunt elsewhere based on flood reports."

4.2.1.4. Critical Lake Elevations for Recreation

Lake elevations are an important factor for water- and shore-based recreation at Wilson Reservoir. Working with the USACE lake staff and KDWP fisheries experts, critical lake elevations for recreation were identified at Wilson Reservoir as well as the corresponding impacts to visitation. These lake elevations are used in the recreation modeling effort to assess the impacts to visitation and economic benefits under FWOP conditions. Other important water surface elevations for the reservoirs are part of the lake level management plans, which specify lake elevations to support fish and wildlife. It is important to note that water surface elevation and depth of water are not equivalent. For example, the water surface elevation may rise five feet above the multi-purpose pool, but if 10 feet of sedimentation were to accrue at the bottom of the lake, then the lake's depth would decrease five feet. This is not accounted for quantitatively in the model, but it is important to consider it qualitatively when assessing impacts of water surface elevation and depth to recreation, especially boating and fishing. Future reservoir sedimentation for Wilson Reservoir and any impacts to recreation are described in Section 4.2.1.2.1.

4.2.1. Future Without Project Conditions

This section considers the impact of future conditions on recreation, including sediment, water surface elevations, water quality and fishery conditions. The first few sections describe how sediment and water surface elevations will change under the four FWOP scenarios, and how these changes will impact visitation and economic benefits. A qualitative evaluation of how changes in water quality and fishery conditions will affect recreation in the future is provided in Sections 4.2.1.4 and 4.2.1.5, respectively.

4.2.1.1. Changes in Sediment and Water Surface Elevations

This section considers three precipitation conditions and their impacts on visitation and economic benefits under the FWOP scenarios, including typical precipitation periods, drought periods, and high water or flooding periods. To identify the drought and flood years or periods, average annual elevations were analyzed across the period of record. Two years were chosen to evaluate flood conditions, with average annual elevations at Wilson Reservoir above 1,518 feet NGVD 29, while 24 years were chosen to evaluate drought conditions, with average annual elevations below 1,512 feet NGVD 29. Where drought years occurred over several years they are assessed as a drought period. Impacts to recreation from flooding start to occur above 1,518 feet NGVD 29 with impacts to water based access and camping and day use affected. At 1,529 feet NGVD 29 most of the recreation areas and parks are closed. Wilson Reservoir frequently experiences drought conditions and high evaporation with extended periods of drought often occurring. At 1,512 feet NGVD 29 the reservoir is four feet below top of multipurpose pool and boat ramps are difficult to access and water-based recreation is considerably decreased with almost no water-based recreation access. Boating safety is a high concern for all visitors from unmarked underwater hazards. See Table 93 and Table 94 for a description of impacts to recreation at different lake elevation thresholds.

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Table 93	Critical	l ake Elev	ations for	Recreation	at Wilson	Reservoir ¹
Table 33.	United	Lake LIEV		Necreation		116361 1011

Lake Elevations	<1,512 ft	1,512-1,515 ft	1,515-1,518; multi-purpose pool is 1,516 ft	1,518-1,524 ft	1,524-1,529 ft	>1,529 ft
Visitation Impacts	Boat ramps are difficult to access, and water- based visitation is considerably decreased. No real impacts to campsites or facilities but lack of water access deters visitation.	Approximately 40% of ramps become inaccessible in this range.	Normal recreational conditions. 100% accessible ramps.	Impacts to water-based access, camping and day use from high water levels. Approximately half of the recreation areas are closed and/or half of the lake visitation is affected.	Impacts to water-based access, camping and day use from high water levels. Approximately 3/4 of the recreation areas are closed and/or half of the lake visitation is affected.	Most of the recreation areas and parks are closed.
Quality of Recreation Effects	Aesthetic values decrease dramatically as exposed shorelines grow. Boating safety is a high concern for all visitors due to increase of unmarked underwater hazards.	Underwater hazards begin to surface; boating safety becomes an elevated concern for all boating visitors.	Normal recreational conditions.	Hazards become hidden by flood waters; boating safety becomes an elevated concern for all boating visitors; roadways become inundated, sewage lift stations have to be closed, limited vehicular access around the park.	Hazards become hidden by flood waters; boating safety becomes an elevated concern for all boating visitors; roadways become inundated, sewage lift stations have to be closed, limited vehicular access around the park.	Closed

¹ The information in this table was developed with input from USACE and KDWP staff familiar with Wilson Reservoir. Lake elevations are in NGVD 1929

Table 94. Percent of Reservoir Impacted by Critical Lake Elevation Thresholds

Lake Elevations	<1,512 ft	1,512-1,515 ft	1,515-1,518; multi-purpose pool is 1,516 ft	1,518-1,524 ft	1,524-1,529 ft	>1,529 ft
Water-based Visitor Impacts	100%	40%	0%	50%	75%	100%
Shore-based Visitor Impacts	0%	0%	0%	50%	75%	100%

The information in this table was developed with input from USACE and KDWP staff familiar with Wilson Reservoir. Lake elevations are in NGVD 1929.

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Drought years/periods include:

- 2025-2031 (1921-1927)
- 2038 (1934)
- 2041 (1937)
- 2058-2060 (1954-1956)
- 2093-2096 (1989-1992)
- 2108-2111 (2004-2017)
- 2117-2120 (2013-2016)

Flood years include:

- 2055 (1951)
- 2097 (1993)

Typical years include all other years.

4.2.1.1.1. Sediment Conditions

It is estimated that approximately 459 acre-feet of sediment accumulates on average annually in Wilson Reservoir. Sediment will continue to accumulate in Wilson Reservoir with an expected additional 8.7% loss of the multipurpose pool over the next 25 years (2049) and 13.2% loss over the next 50 years (2074) (Appendix D) bringing the capacity of the multipurpose pool to 203,400 acre-feet in 2074. Sedimentation has not generally impacted recreation at Wilson Reservoir but some shoreline erosion and deposition of silt has become an increasing concern.

While sediment will continue to accumulate (8.7% loss of the multipurpose pool over the next 25 years and 13.2% loss over the next 50 years) and the delta could extend, the size of the multipurpose pool and the lake's recreational opportunities are expected to be impacted very minimally. Figure 33, Figure 34, Figure 35 and Figure 36 show the depths of Wilson Reservoir at multi-purpose pool in 2024, 2049 (25 years), 2074 (50 years), and 2124 (100 years). In terms of sediment concerns Wilson Reservoir doesn't have as many issues compared to Kanopolis Reservoir and other lakes. Sediment modeling shows that Cedar Creek boat ramp is currently not accessible. Wilson Reservoir staff indicated that small craft boating is currently accessible at/near multipurpose pool (shallow watercraft ex. Jon boats). Visitation is primarily shallow watercraft for hunting/fishing and dependent on elevations (Kanopolis and Wilson Lake Meeting, 1/15/21). An estimated 3,466 visitors came to this area in 2018. Additionally, Elm Creek boat ramp appears to be inaccessible after 2124. Visitation to this area was 3,466 in 2018. Other areas that are projected to be impacted by sediment (by 2124) include: 2 boat ramps at Minooka Park.

4.2.1.1.1. Water Surface Elevations

Wilson Reservoir does not loose significant storage over the 100-years of the FWOP. However, the average and median FWOP elevations are all below the top of multipurpose pool which is reflective of



Figure 33. Wilson Reservoir Baseline Depths - 2024



Figure 34. Wilson Reservoir Future Depths with Projected Sedimentation – 2049 (25 Years)



Figure 35. Wilson Reservoir Future Depths with Projected Sedimentation – 2074 (50 Years)



Figure 36. Wilson Reservoir Future Depth with Projected Sedimentation - 2124 (100 Years)

the frequent drought conditions observed there. The FWOP 2024 and FWOP 2049 scenarios are very similar as the sediment conditions do not change dramatically in this timeframe for Wilson Reservoir. However, as more sediment accumulates with each additional FWOP scenario the average pool elevation also increases (Appendix B).

Wilson Reservoir modeling shows that the pool elevation does not drop as far into the multipurpose pool in the later FWOP scenarios (Table 95). This is likely because of reduced evaporation from smaller pool areas as evaporation is a large driver of pool elevation at Wilson Reservoir. Additional information is provided in Appendix B.

FWOP Scenario	Average Water Surface Elevations (feet)	Change in Average Water Surface Elevations from 2024 (feet)
2024	1,513.2	-
2049	1,513.2	+0.08
2074	1,513.4	+0.23
2124	1,513.6	+0.46

Table 95. Average Water Surface Elevations at Wilson Reservoir

Note: The top of the multi-purpose pool is 1,516 feet, NGVD 29. Represents average across the period of record.

There are seven notable drought periods assessed for Wilson Reservoir over the 100-period of analysis: 2025-2031 (translates to past years of 1921-1927), 2038 (translates to past year of 1934), 2041 (translates to past year of 1937), 2058-2060 (translates to past years of 1954-1956), 2093-2096 (translates to past years of 1989-1992), 2108-2111 (translates to past years of 2004-2017), and 2117-2120 (translates to past years of 2013-2016). There are two notable high water or flood years over the 100-year period of analysis: 2055 (translates to past year of 1951) and 2097 (translates to past year of 1993).

Under both flooding and drought conditions, on average, pools levels are higher in FWOP 2049, 2074, and 2124 conditions than experienced under FWOP 2024 conditions (which are approximately nine feet above for flood years and five feet below for drought years of top of multi-purpose pool on average) (Table 96). During drought conditions, on average, pool levels in 25 years (2049) are approximately 0.16 feet higher, while in 50 and 100 years, pool levels are approximately 0.49 to 1.03 feet higher on average under FWOP 2074 and FWOP 2124 FWOP conditions, respectively, compared to FWOP 2024. This is still greater than nine feet below the top of multi-purpose pool experience under baseline conditions.

Table 50. Average Annual Water Gunace Elevations During Drought and Flood Tears						
FWOP Scenario	Change in Average Water Surface Elevations from 2024 During Drought Years (feet)	Change in Average Water Surface Elevations from 2024 During Flood Years (feet)				
2049	+0.16	+0.04				
2074	+0.49	+0.14				
2124	+1.03	+0.36				

Table 96. Average Annual Water Surface Elevations During Drought and Flood Years

Note: The top of the multi-purpose pool is 1,516 feet, NGVD 29.

Drought conditions, similar to those experienced in past drought periods, result in relatively lower water surface elevations (between five and 19 feet below multi-purpose pool) for one to six years, which could result in severe implications for recreation at Wilson Reservoir. See Section 4.2.1.2.2 for more detail on drought impacts to recreation.

Under two notable high water or flood years over the 100-year period of analysis, as shown in Table 96, on average, water surface elevations are higher on average under the FWOP 2049, 2074, and 2124

conditions compared to FWOP 2024 (which are approximately nine feet above top of multi-purpose pool on average). During peak water surface elevations in these years, the difference among the water surface elevations under all FWOP scenarios is minimal (0.04 to 0.36 feet higher).

The worst modeled future flood year in terms of visitation was in 2055 (compared to 1951) when, during the year, water surface elevations were above elevation 1,525 feet NGVD29 (see threshold table in existing conditions section) for an extended period of time under all of the FWOP scenarios. In general, Wilson Reservoir is closed to 75% visitation when water surface elevations are 1,524 feet NGVD 29.

4.2.1.2. Changes in Visitation

This section describes how changes and lake elevations can potentially impact visitation at Wilson Reservoir. Impacts from sediment are not discussed as Wilson Reservoir does not loose significant storage over the 100 years of the FWOP. In the following sections the potential impacts to visitation are described compared to all visitation during typical conditions at the lake-elevation affected recreation areas under the baseline year, 2018. In 2018, 418,200 people visited recreation areas that are potentially impacted by lake elevations, which includes dispersed recreation. The study team also compared the impacted visitation to 2018 baseline visitation at all locations at Wilson Reservoir. In 2018, visitation across Wilson Reservoir was estimated to be 461,300.

4.2.1.2.1. Typical Precipitation Conditions

Drought conditions are the main driver of recreation impacts across the reservoir, although flood conditions can exacerbate these impacts to recreation further decreasing access and quality of recreation at the reservoir. Under typical precipitation visitation under the 100 years of the FWOP is assumed to remain similar to past visitation.

4.2.1.2.2. Drought Conditions

During drought conditions, notably the period between 2025 and 2031, consistent with the historic drought of 1920s, water surface elevations are considerably lower than the top of multipurpose pool across all FWOP scenarios (from five to 19 feet lower than multi-purpose pool during this period) and considerably below thresholds important for recreation. In drought conditions, consistent with the 1920s water conditions, all water-based access at recreation areas at the lake would be impacted under all FWOP scenarios. These drought events would have multi-year impacts as the fishery would be impacted, recreation infrastructure (e.g., boat ramps) may require repairs and modifications, visitation would be severely impacted, and revenue sources to maintain the lakes would decrease.

Modeling of water surface elevations and critical lake elevations for recreation in the FWOP 2024 scenario show that in 2025 to 2031 (modeled after 1920s drought conditions, the largest reduction in water surface elevations), visitation at the recreation areas that could potentially be impacted by changes in lake elevations would be on average annually 295,500, a reduction of approximately 165,800 visitors from 2018 baseline conditions at lake-elevation affected recreation areas. The other drought years/periods would have similar impacts to visitation as the 2025 to 2031 drought period.

4.2.1.2.3. Flood Conditions

Within the 100-year period of analysis, considerable flood events would occur under the FWOP in 2055 (modeled after 1951 conditions) and 2097 (1993). Modeling of water surface elevations and critical lake elevations for recreation in FWOP 2024, FWOP 2049, FWOP 2074, and FWOP 2124 conditions show considerable impacts to visitation at the recreation areas adjacent to the lake in these years (Table 97, 98, 99, and 100). A reduction in visitation at recreation areas impacted by changes in water surface elevations at Wilson Reservoir in 2055, consistent with conditions experienced in 1951, indicates a potential

visitation decrease of 62% to 73% at lake-elevation affected areas compared to baseline conditions at Wilson Reservoir (2018).

Table 97 below shows how flood conditions under the FWOP 2024 affect recreation in areas affected by changes in lake elevations by comparing visitation at those areas in modeled "flood years" (2055 and 2097) to baseline conditions (2018).

Flooding Years	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Percent Decrease in Visitation at Lake-Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018) at All Recreation Areas
Visitation under Baseline Conditions (2018)	418,200	-	-	461,300
2055	113,100	-305,100	-73%	-66%
2097	158,700	-259,500	-62%	-56%

Table 97 Annual	Changes in V	lisitation A	seociated w	ith Modeled	Flood Events	FWOP 2	024
Table 57. Allitual	Changes in v	ISILALION P	ASSOCIATED W		FIOOU Events,	FWUF 2	024

With flooding conditions, potentially more shore-based visitors could be impacted in the recreation areas around the lake as flooding can impact roads, trails and campgrounds with slightly higher reservoir elevations under future conditions compared to the FWOP 2024 scenario. If all water- and shore-based visitors in the recreation areas adjacent to the lake are impacted during flooding conditions, 418,200 visitors would be affected, representing 91% of visitation under baseline conditions at Wilson Reservoir (2018). Table 98, 99, and 100 below show how flood conditions under the 2049, 2074, and 2124 FWOP scenarios affect recreation in areas affected by changes in lake elevations by comparing visitation at those areas in modeled "flood years" (2055 and 2097) to baseline conditions (2018).

Table 98. Annual Change	s in Visitation Associated	with Modeled Flood	Events, FWOP 2049
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Flooding Years	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Percent Decrease in Visitation at Lake-Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018) at All Recreation Areas	
Visitation under Baseline Conditions (2018)	418,200	-	-	461,300	
2055	112,300	-305,900	-73%	-66%	
2097	159,700	-258,500	-62%	-56%	

Flooding Years	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Percent Decrease in Visitation at Lake-Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018) at All Recreation Areas	
Visitation under Baseline Conditions (2018)	418,200	-	-	461,300	
2055	112,000	-306,200	-68%	-66%	
2097	158,700	-258,500	-62%	-56%	

Table 100. Annual Changes in Visitation Associated with Modeled Flood Events, FWOP 2124

Flooding Years	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Percent Decrease in Visitation at Lake-Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018) at All Recreation Areas
Visitation under Baseline Conditions (2018)	418,200	-	-	461,300
2055	111,400	-306,800	-73%	-67%
2097	156,100	-261,100	-62%	-57%

Impacts on visitation under the two flood events could be high similar to past flood events. However, comparing water surface elevation impacts on visitation under the 2049, 2074, and 2124 FWOP scenarios during the three flood events, water surface elevations are minimally impacted (2049 - 0.1 foot increase; 2074 - 0.1 foot increase; and 2124 - 0.4 foot increase) compared to FWOP 2024. These minimal changes in water surface elevations under the two FWOP scenarios compared to FWOP 2024 during the two flood events has minimal effect on visitation compared to baseline visitation (2018) and shows some minor increases in impacts as shown in Table 98, 99, and 100.

4.2.1.3. Changes in Economic Benefits

4.2.1.3.1. Consumer Surplus

Consumer surplus values are measured through the Corps' Unit Day Value (UDV) approach further described in Section 2.0. This section describes how changes and lake elevations and sediment conditions can potentially impact recreation consumer surplus values. Sediment deposition and relatively lower and higher water surface elevations have direct impacts on water-based visitors (boaters, swimmers, anglers) and indirect impacts to shore-based visitors for the recreation areas adjacent to the lake (termed lake-elevation affected recreation areas). In the following sections, we describe the potential impacts to consumer surplus values compared to all recreation values during typical conditions at the lake-elevation affected recreation areas under the baseline year, 2018.

Typical Precipitation Conditions

Visitation during baseline conditions at the recreation areas that are potentially impacted by lake elevations (including dispersed recreation) support an estimated \$5.5 million in consumer surplus value. The study team also compared the impacted consumer surplus values to baseline visitation and values

(2018) at all locations at Wilson Reservoir. In 2018, visitation across Wilson Reservoir supported approximately \$6.2 million in consumer surplus values.¹⁰

Impacts from sediment are not discussed as Wilson Reservoir does not lose significant storage over the 100 years of the FWOP.

Drought Conditions

The impacts to visitation during an extreme drought would impact all water-based visitation at lakeelevation impacted recreation areas under all FWOP scenarios. Drought conditions can also affect shorebased visitors if the lake shore is further away from camping and picnic area, or if shallow pools pose unappealing features or conditions (e.g., odors, swampy areas, mosquitoes, etc.). With elevations below 1,512 feet NGVD 29, an estimated 100% of water-based visitors could be impacted (see Table 93 and Table 94).

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024, FWOP 2049, FWOP 2074, and FWOP 2124 conditions are very similar and show that in modeled droughts years reduced visitation would translate to a potential loss in consumer surplus values during drought conditions of approximately \$1.4 to \$1.7 million annually (Table 101, Table 102, Table 103, and Table 104). These reductions in visitation in the recreation areas impacted by changes in lake elevations represent an annual decrease of 25% to 31% compared to 2018 baseline conditions.

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake-Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus at Lake- Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus (2018)
Baseline condition (2018)	418,200	-	\$5.5 million	\$5.5 million	\$6.2 million
2025-2031	295,400	-122,800	-\$1.7 million	-31%	-27%
2038	293,100	-125,100	-\$1.7 million	-31%	-27%
2041	308,700	-109,500	-\$1.5 million	-27%	-24%
2058-2060	293,200	-125,000	-\$1.7 million	-31%	-27%
2093-2096	293,300	-124,900	-\$1.7 million	-31%	-27%
2108-2111	293,200	-125,000	-\$1.7 million	-31%	-27%
2117-2120	298,700	-119,500	-\$1.6 million	-29%	-26%

 Table 101. Annual Visitation and Consumer Surplus Changes Associated with Drought Events,

 FWOP 2024 (Consumer Surplus is expressed in FY22\$)

¹⁰ Consumer surplus values are estimated with recreation visitor day and the Corps' UDV approach. In the modeling effort, visits were converted to recreation visitor days to apply the UDV using an estimate of average number of days per trip at the Kansas City District lakes to estimate consumer surplus. In this appendix, visitation is presented and described for consistency, and not recreation visitor days.
Table 102. Annual Visitation and Consumer Surplus Changes Associated with Drought Events,FWOP 2049 (Consumer Surplus is expressed in FY22\$)

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake-Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus at Lake- Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus (2018)
Baseline condition (2018)	418,200	418,200	\$5.5 million	\$5.5 million	\$6.2 million
2025-2031	295,900	-122,300	-\$1.7 million	-31%	-27%
2038	293,100	-125,100	-\$1.7 million	-31%	-27%
2041	305,700	-112,500	-\$1.5 million	-27%	-24%
2058-2060	295,100	-123,100	-\$1.7 million	-31%	-27%
2093-2096	293,200	-125,000	-\$1.7 million	-31%	-27%
2108-2111	293,400	-124,800	-\$1.7 million	-31%	-27%
2117-2120	298,800	-119,400	-\$1.6 million	-29%	-26%

Table 103. Annual Visitation and Consumer Surplus Changes Associated with Drought Events,FWOP 2074 (Consumer Surplus is expressed in FY22\$)

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake-Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus at Lake- Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus (2018)
Baseline condition (2018)	418,200	418,200	\$5.5 million	\$5.5 million	\$6.2 million
2025-2031	296,300	-121,900	-\$1.7 million	-31%	-27%
2038	297,000	-121,200	-\$1.6 million	-29%	-26%
2041	307,300	-110,900	-\$1.5 million	-27%	-24%
2058-2060	296,600	-121,600	-\$1.6 million	-29%	-26%
2093-2096	293,300	-124,900	-\$1.7 million	-31%	-27%
2108-2111	297,300	120,900	-\$1.6 million	-29%	-26%
2117-2120	298,900	119,300	-\$1.6 million	-29%	-26%

Table 104. Annual Visitation and Consumer Surplus Changes Associated with Drought Events,FWOP 2124 (Consumer Surplus is expressed in FY22\$)

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake-Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus at Lake- Elevation Affected Areas	Percent Decrease from Baseline Consumer Surplus (2018)
Baseline condition (2018)	418,200	418,200	\$5.5 million	\$5.5 million	\$6.2 million
2025-2031	298,600	-119,600	-\$1.6 million	-29%	-26%
2038	308,200	-110,000	-\$1.5 million	-27%	-24%
2041	314,300	-103,900	-\$1.4 million	-25%	-23%
2058-2060	299,000	-119,200	-\$1.6 million	-29%	-26%
2093-2096	293,400	-124,800	-\$1.7 million	-31%	-27%
2108-2111	313,000	-105,200	-\$1.4 million	-25%	-23%
2117-2120	299,100	-119,100	-\$1.6 million	-29%	-26%

Flood Conditions

Within the 100-year period of analysis, considerable flood events would occur in 2055 (modeled after 1951 conditions) and 2097 (1993). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024, FWOP 2049, FWOP 2074, and FWOP 2124 are very similar and conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss in consumer surplus values during flood conditions of between \$3.4 and \$4.1 million in consumer surplus values, representing a decrease between 62% and 75% of total consumer surplus at Wilson Reservoir under baseline conditions (Table 105, Table 106, Table 107, and Table 108 below). There could also be impacts to visitation at the recreation areas below the dam (e.g., Sylvan Park) with potentially higher releases from the dam and localized flooding below the dam, although these impacts were not modeled.

Table 105. Annual Visitation and Consumer Surplus Changes Associated with Modeled FloodEvents, FWOP 2024 (*Consumer Surplus is expressed in FY22\$)

Flood Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake-Elevation Affected Areas	Percent Decrease in Visitation at Lake- Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018)
Baseline condition (2018)	418,200		\$5.5 million	\$5.5 million	\$6.2 million
2055	113,100	-305,100	-\$4.0 million	-73%	-65%
2097	158,700	-259,500	-\$3.4 million	-62%	-55%

 Table 106. Annual Visitation and Consumer Surplus Changes Associated with Modeled Flood

 Events, FWOP 2049 (Consumer Surplus is expressed in FY22\$)

Flood Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake-Elevation Affected Areas	Percent Decrease in Visitation at Lake- Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018)
Baseline condition (2018)	418,200	418,200	\$5.5 million	\$5.5 million	\$6.2 million
2055	112,300	-305,900	-\$4.0 million	-73%	-65%
2097	159,700	-258,500	-\$3.4 million	-62%	-55%

 Table 107. Annual Visitation and Consumer Surplus Changes Associated with Modeled Flood

 Events, FWOP 2074 (Consumer Surplus is expressed in FY22\$)

Flood Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake-Elevation Affected Areas	Percent Decrease in Visitation at Lake-Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018)
Baseline condition (2018)	418,200	418,200	\$5.5 million	\$5.5 million	\$6.2 million
2055	112,000	-306,200	-\$4.1 million	-75%	-66%
2097	158,700	-259,500	-\$3.4 million	-65%	-55%

 Table 108. Annual Visitation and Consumer Surplus Changes Associated with Modeled Flood

 Events, FWOP 2124 (Consumer Surplus is expressed in FY22\$)

Flood Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Consumer Surplus at Lake-Elevation Affected Areas	Percent Decrease in Visitation at Lake-Elevation Affected Areas	Percent Decrease from Baseline Visitation (2018)
Baseline condition (2018)	418,200	418,200	\$5.5 million	\$5.5 million	\$6.2 million
2055	111,400	-306,800	-\$4.1 million	-75%	-66%
2097	156,100	-262,100	-\$3.5 million	-64%	-56%

4.2.1.3.2. Regional Economic Benefits

Regional economic impacts are estimated through the Corp's RECONS model and further described in Section 2. This section describes how changes and lake elevations and sediment conditions can potentially impact regional economic benefits (jobs and income) to adjacent communities. Visitors spend their money in local communities, providing regional economic benefits in these communities. Sediment deposition and relatively lower and higher water surface elevations have direct impacts on water-based visitors (boaters, swimmers, anglers) and indirect impacts to shore-based visitors for the recreation areas adjacent to the lake (termed lake-elevation affected recreation areas). In the following sections, the study team describes the potential impacts to regional economic benefits from reduced visitation compared to regional economic benefits supported under baseline conditions in 2018. Consistent with visitation in 2018, 461,300 visitors support 136 jobs and \$4.3 million in labor income in the local economy under baseline conditions. In the recreation areas potentially affected by changes in lake elevations under baseline conditions, 418,200 visitors support 125 jobs and \$4.0 million in labor income.

Typical Precipitation Conditions

Drought conditions are the main driver of recreation impacts across the reservoir, although flood conditions can exacerbate these impacts to recreation further decreasing access and quality of recreation at the reservoir. Under typical precipitation visitation under the 100 years of the FWOP is assumed to remain similar to past visitation.

Impacts from sediment are not discussed as Wilson Reservoir does not lose significant storage over the 100 years of the FWOP.

Drought conditions

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled drought years/periods of 2025-2031 (translates to past years of 1921-1927), 2038 (1934), 2041 (1937), 2058-2060 (1954-1956), 2093-2096 (1989-1992), 2108-2111 (2004-2017), and 2117-2120 (modeled after 2013-2016 conditions), reduced visitation would lead to a potential loss of 52 to 60 jobs and \$1.8 to \$2.1 million during drought conditions under 2024 FWOP compared to baseline conditions (Table 109). These reductions in economic benefits impacted by changes in lake elevations represent a 42% to 49% decrease in jobs from total jobs supported from all visitor spending at Wilson Reservoir under baseline conditions (136 annual jobs). Droughts can also have lasting impacts to tourism business depending on the timing of the recovery and resiliency of the businesses, including the reservoir refilling, the re-establishment of the fishery, steps to mitigate losses in visitation, and the demand for recreation at the lake.

 Table 109. Annual Visitation and Changes in Regional Economic Benefits Associated with

 Drought Events, FWOP 2024 (Labor income is expressed in FY22\$)

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake-Elevation Affected Areas from Baseline Visitation	Reduction in Jobs at Lake- Elevation Affected Areas	Reduction in Labor Income at Lake- Elevation Affected Areas	Percent Decrease in Jobs and Income from Baseline Conditions
Baseline condition (2018)	418,200	-	125	\$4.0 million	136 jobs; \$4.3 million in Iabor income
2025-2031	295,400	-122,800	-59	-\$2.0 million	-47%
2038	293,100	-125,100	-60	-\$2.1 million	-49%
2041	308,700	-109,500	-52	-\$1.8 million	-42%
2058-2060	293,200	-125,000	-60	-\$2.1 million	-49%
2093-2096	293,300	-124,900	-60	-\$2.1 million	-49%
2108-2111	293,200	-125,000	-60	-\$2.1 million	-49%
2117-2120	298,700	-119,500	-57	-\$2.0 million	-47%

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2049 conditions show that in modeled drought years of 2025-2031 (translates to past years of 1921-1927), 2038 (1934), 2041 (1937), 2058-2060 (1954-1956), 2093-2096 (1989-1992), 2108-2111 (2004-2017), and 2117-2120 (modeled after 2013-2016 conditions), reduced visitation would lead to a potential loss of 57 to 60 jobs and \$1.9 to \$2.1 million during drought conditions under 2024 FWOP compared to baseline conditions (Table 110). These reductions in economic benefits impacted by changes in lake elevations represent a 44% to 49% decrease in jobs from total jobs supported from all visitor spending at Wilson Reservoir under baseline conditions (136 annual jobs).

Table 110. Annual Visitation and Changes in Regional Economic Benefits Associated withDrought Events, FWOP 2049 (Labor income is expressed in FY22\$)

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake-Elevation Affected Areas from Baseline Visitation	Reduction in Jobs at Lake- Elevation Affected Areas	Reduction in Labor Income at Lake- Elevation Affected Areas	Percent Decrease in Jobs and Income from Baseline Conditions
Baseline condition (2018)	418,200	-	125	\$4.0 million	136 jobs; \$4.3 million in Iabor income
2025-2031	295,900	-122,300	-58	-\$2.0 million	-47%
2038	293,100	-125,100	-60	-\$2.0 million	-47%
2041	305,700	-112,500	-54	-\$1.9 million	-44%
2058-2060	295,100	-123,100	-59	-\$2.0 million	-47%
2093-2096	293,200	-125,000	-60	-\$2.1 million	-49%
2108-2111	293,400	-124,800	-59	-\$2.1 million	-49%
2117-2120	298,800	-119,400	-57	-\$2.0 million	-47%

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2074 conditions show that in modeled drought years of 2025-2031 (translates to past years of 1921-1927), 2038 (1934), 2041 (1937), 2058-2060 (1954-1956), 2093-2096 (1989-1992), 2108-2111 (2004-2017), and 2117-2120 (modeled after 2013-2016 conditions), reduced visitation would lead to a potential loss of 53 to 60 jobs and \$1.8 to \$2.1 million during drought conditions under 2024 FWOP compared to baseline conditions (Table 111). These reductions in economic benefits impacted by changes in lake elevations represent a 42% to 49% decrease in jobs from total jobs supported from all visitor spending at Wilson Reservoir under baseline conditions (136 annual jobs).

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Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake-Elevation Affected Areas from Baseline Visitation	Reduction in Jobs at Lake- Elevation Affected Areas	Reduction in Labor Income at Lake- Elevation Affected Areas	Percent Decrease in Jobs and Income from Baseline Conditions
Baseline condition (2018)	418,200	-	125	\$4.0 million	136 jobs; \$4.3 million in labor income
2025-2031	296,300	-121,900	-58	-\$2.0 million	-47%
2038	297,000	-121,200	-58	-\$2.0 million	-47%
2041	307,300	-110,900	-53	-\$1.8 million	-42%
2058-2060	296,600	-121,600	-58	-\$2.0 million	-47%
2093-2096	293,300	-124,900	-60	-\$2.1 million	-49%
2108-2111	297,300	-120,900	-58	-\$2.0 million	-47%
2117-2120	298,900	-119,300	-57	-\$2.0 million	-47%

Table 111. Annual Visitation and Changes in Regional Economic Benefits Associated with
Drought Events, FWOP 2074 (Labor income is expressed in FY22\$)

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2124 conditions show that in modeled drought years of 2025-2031 (translates to past years of 1921-1927), 2038 (1934), 2041 (1937), 2058-2060 (1954-1956), 2093-2096 (1989-1992), 2108-2111 (2004-2017), and 2117-2120 (modeled after 2013-2016 conditions), reduced visitation would lead to a potential loss of 50 to 59 jobs and \$1.7 to \$2.1 million during drought conditions under 2024 FWOP compared to baseline conditions (Table 112). These reductions in economic benefits impacted by changes in lake elevations represent a 40% to 49% decrease in jobs from total jobs supported from all visitor spending at Wilson Reservoir under baseline conditions (136 annual jobs).

Table 112. Annual Visitation and Changes in Regional Economic Benefits Associated with Drought Events, FWOP 2124 (Labor income is expressed in FY22\$)

Drought Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake-Elevation Affected Areas from Baseline Visitation	Reduction in Jobs at Lake- Elevation Affected Areas	Reduction in Labor Income at Lake-Elevation Affected Areas	Percent Decrease in Jobs and Income from Baseline Conditions
Baseline condition (2018)	418,200	-	125	\$4.0 million	136 jobs; \$4.3 million in labor income
2025-2031	298,600	-119,600	-57	-\$2.0 million	-47%
2038	308,200	-110,000	-52	-\$1.8 million	-42%
2041	314,300	-103,900	-50	-\$1.7 million	-40%
2058-2060	299,000	-119,200	-57	-\$2.0 million	-47%
2093-2096	293,400	-124,800	-59	-\$2.1 million	-49%
2108-2111	313,000	-105,200	-50	-\$1.7 million	-40%
2117-2120	299,100	-119,100	-57	-\$2.0 million	-47%

Flood Conditions

Within the 100-year period of analysis, considerable flood events would occur in 2055 (modeled after 1951 conditions) and 2097 (1993). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss of 76 to 92 jobs and \$2.4 to \$2.9 million in labor income, representing a decrease between 56% to 67% of total jobs supported by visitor spending at Wilson Reservoir under baseline conditions (Table 113). There could also be impacts to visitation at the recreation areas below the dam (e.g., Sylvan Park) with potentially higher releases from the dam and localized flooding below the dam, although these impacts were not modeled.

Table 113. Annual Visitation and Changes in Regional Economic Benefits Associated with Flood
Events, FWOP 2024 (Labor income is expressed in FY22\$)

Flood Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake Elevations	Reduction in Visitation at Lake- Elevation Affected Areas from Baseline Visitation	Reduction in Jobs at Lake- Elevation Affected Areas	Reduction in Labor Income at Lake- Elevation Affected Areas	Percent Decrease in Jobs and Income from Baseline Conditions
Baseline condition (2018)	418,200	-	125	\$4.0 million	136 jobs; \$4.3 million in labor income
2055	113,100	-305,100	-92	-\$2.9 million	-67%
2097	158,700	-259,500	-76	-\$2.4 million	-56%

Under the FWOP 2049, 2074, and 2124 scenarios, water surface elevations are slightly lower on average compared to FWOP 2024 conditions during modeled years of 2055 and 2097. During peak water surface elevations in these years, the difference among the water surface elevations under all FWOP scenarios is minimal and the impacts to the regional economic benefits (i.e., jobs and labor income) remain fairly consistent compared FWOP 2024 for the modeled years of 2055, 2097, and 2124.

The results of the 100-year FWOP scenario (2124) are included in Table 114 for comparison. The FWOP 2049 and FWOP 2074 scenarios have very similar results to the FWOP 2124 scenario.

Flood Year	Modeled Visitation at Recreation Areas Affected by Changes in Lake	Reduction in Visitation at Lake-Elevation Affected Areas from Baseline Visitation	Reduction in Jobs at Lake- Elevation Affected Areas	Reduction in Labor Income at Lake- Elevation Affected Areas	Percent Decrease in Jobs and Income from Baseline Conditions
Baseline condition (2018)	Elevations 418,200	418,200	125	\$4.0 million	136 jobs; \$4.3 million in labor income
2055	111,400	-306,800	-92	-\$3.0 million	-67%
2097	156,100	-262,100	-77	-\$2.4 million	-56%

Table 114. Annual Visitation and Changes in Regional Economic Benefits Associated with Flood Events, FWOP 2124 (Labor income is expressed in FY22\$)

Damages, Revenues, and Fees to States

Visitation to Wilson Reservoir contributes considerable revenue to the state to maintain parks. Revenue is collected through park entrance fees, camping fees, hunting and fishing license revenues, concessionaire fees. In 2018, the state revenues associated with Wilson Reservoir were \$486,000, fifth in revenue in the state of Kansas.¹¹ At Wilson Reservoir in 2019, these revenues were \$527,000, an increase of 8% from 2018 revenues due to increased visitation from flooding events in the surrounding region.

Hunting and fishing license sales are also important for the state, bringing in \$31.2 million in 2018 across the state, although this data is not available by lake. In general, these revenues vary over time and are typically proportional to visitation at the lakes. As described in this section, sediment deposition, droughts, and flooding conditions can have considerable impacts on this visitation and therefore revenue sources for the state. The evaluation indicates that drought conditions could result in an annual decrease of visitation up to 42% of baseline conditions (2018), while flooding impacts would have larger impact, impacting up to 73% of visitation under baseline conditions. These impacts would continue to occur overtime when droughts or flooding occur, with their occurrences becoming more frequent with climate change.

During these extreme events, the state and USACE often incur costs to repair damages, conduct small scale dredging, and other actions to repair or maintain infrastructure. Therefore, the state has less revenues coming in, with increased expenses, often impacting state coffers for years.

Estimated costs for repairs of recreational infrastructure associated with damage from the 2019 flood at USACE-managed recreation areas of Wilson Reservoir were \$453,000. The impacts at the KDWP state parks at Wilson Reservoir include recreation damages were estimated to be \$52,000. These damages are likely to continue to occur in the future with extreme events.

Due to low sedimentation rate, lack of harmful agal blooms, and quality fishing opportunities it is unlikely that use and visitation at Wilson Reservoir will decline significantly in the future (KDWP 2020c).

¹¹These fees and revenues, generally paid by visitors to federal and state governments, are included in the estimate of economic output in described in Section 3.4.1.2.3.

4.2.1.4. Water Quality

Wilson Reservoir has not experienced recreation impacts from HABs. Deteriorating water quality could eventually lead to new occurrence of HABs in Wilson Reservoir with adverse impacts to visitors in the future. Impacts from HABs has been implicated in local economic impact from decrease in tourism/recreational visitation and are expected to continue in the future (Appendix G).

As described it is estimated that approximately 459 acre-feet of sediment accumulates on average annually at Wilson Reservoir. Sediment will continue to accumulate with an expected additional 8.7% loss of the multipurpose pool over the next 25 years and a 13.2% loss over the next 50 years (Appendix D). Reduced volume means less dilution and can equate to higher concentration of nutrients stored in the lake system. With the expected low amount of sediment expected to accumulate in Wilson Reservoir issues related to reduced dilution will not likely impact water quality or recreation at Wilson Reservoir.

Excess chloride and sulfate, caused by naturally occurring salt compounds from the Dakota Aquifer entering from the Saline River via groundwater additions to inflow streams, are the main impairments to Wilson Reservoir. Natural background chloride and sulfate levels on Saline River above Wilson Reservoir consistently exceed water quality criteria of 250 mg/L which prevents achievement of KDHE state water quality criteria of 250 mg/L.

Wilson Reservoir watershed has considerably less row crop agriculture, sediment runoff, fertilizer and pesticide runoff than other lakes in the Kansas River Basin. Water quality can degrade during extended wet periods or flood conditions as observed in 2019. During this time, the degraded conditions are less extreme than those experienced in other watersheds.

All reservoirs in the watershed, including Wilson Reservoir, will likely experience increasing effects of aging. Future water quality within watershed lakes is dependent on multiple influencing factors, some of which are challenging to predict and/or estimate. It can be assumed that continued, and increasing fertilizer use, will continue to influence the water quality of runoff, groundwater, streams, and lakes. Continued and enhanced water quality impairment may be expected at Wilson Reservoir. Consistent with existing conditions, storm events generating high run-off volumes will continue to transport the majority of sediment and nutrient loads to the reservoir. Based on an assessment of runoff/streamflow, sediment yield, and TN and TP yield under climate change runoff to Wilson Reservoir is expected to have a low increase in runoff/streamflow, sediment yield, TN yield, and TP yield as Wilson Reservoir is considered the "clearest lake in Kansas" as a result of considerably less row crop agriculture, sediment runoff, fertilizer and pesticide runoff than other lakes in the basin.

Water residence times were estimated for Wilson Reservoir (Appendix G). Extended residence time allows for longer dilution and settling time as well as biological attenuation of agricultural runoff which improves water quality downstream of Wilson Reservoir. A reduction in residence time results in less time for nutrient and sediment constituents to settle within reservoirs and then passing them downstream. Reservoirs with higher sedimentation rates that are losing large portions of their multipurpose pool have the largest decreases in residence time expected in the future. Wilson Reservoir does not have a high sedimentation rate expected over the next 100 years and is estimated to have a reduction in residence time of 15% under the FWOP 2124. There will likely be a seasonality to these reductions in residence time with greater reductions during the wetter periods and increases during the drier periods.

Impacts are expected to continue and potentially increase (see Appendix G) in the future causing reduced visitation and reduced visitor experience at Wilson Reservoir.

4.2.1.5. Angling and Sport Fishery

Biennial stockings for striped bass will continue to be requested from the culture system. Walleye and blue catfish will be stocked as needed, generally when natural recruitment fails for one to three years.

Wilson Reservoir was ranked as the most preferred reservoir to fish by anglers during the 2013 Licensed Angler Survey. Due to low sedimentation rate, lack of harmful agal blooms, and quality fishing opportunities it is unlikely that use and visitation at Wilson Reservoir will decline significantly in the next 100 years. Angling will continue at Wilson Reservoir in the future, but targeted species may vary depending on fluctuating factors that affect fish abundance and condition or their habitat. If a fish species highly sought by anglers declines this could affect the angling experience in the future and fisherman may choose to move to another reservoir.

Water levels will continue to fluctuate due to the variable annual precipitation in the region with drought conditions in some years that cause a decline in pool elevations and inundation of specific habitats (e.g., coves, shorelines) leading to a lack of vegetation and structure near the shoreline used for fish spawning and escape habitat. In other years high water elevations that are sustained will provide excellent habitat for young of the year fish allowing some fish species to have good year classes recruited to the fishery (e.g., largemouth bass). However, significant flooding can kill large areas of common reed grass and shoreline vegetation utilized by fish species. Zebra mussels and white perch could continue to increase at Wilson Reservoir altering food webs in the reservoir and consuming fish eggs creating recruitment issues for sport fish.

While sedimentation will continue to occur (3.3% loss of the multipurpose pool over the next 50 years) it is not expected to create impacts to reservoir fisheries or their habitat in the future. Shoreline erosion and deposition of silt will continue to cause stressors to fish populations leaving littoral areas unvegetated and silting in important areas fish use for spawning, nursery habitat, and protective cover.

KDWP will continue to monitor and regulate sport fishing populations to provide the best conservation of the resource for anglers. Habitat improvements, most likely in the form of brush piles as fish attractors and shoreline vegetation for improved littoral productivity, will be accomplished intermittently. Boat ramps will continue to be assessed to provide reasonable boat access for anglers. Shoreline access will be maintained for bank anglers.

Fisheries management objectives will continue to optimize the quality and diversity of angling opportunities through enhancement of population abundance as needed. Fisheries management measures will continue to include fish harvest regulations, habitat work, aquatic vegetation enhancement, fish stocking, and special studies, and sampling to monitor trends. Creel surveys for angler use and preferences will also continue to support management of the fisheries. Fish species that inhabit Wilson Reservoir are not expected to change in the future but will have periods where changes in abundance and shifts in sportfish species dominance occur from conditions that affect habitat quantity and quality, similar to what is now experienced at Wilson Reservoir (Appendix E).

4.3. Cedar Bluff Reservoir

Cedar Bluff State Park surrounds Cedar Bluff Reservoir, which is located on the Smoky Hill River in west central Kansas about 15 miles south of WaKeeney (Figure 37). Cedar Bluff State Park is divided into two, unique areas along the shorelines of Cedar Bluff Reservoir. The Bluffton Area, on the north shore, provides nearly 350 acres for visitors. The Page Creek Area, on the south shore of the reservoir, is nearly 500 acres in size. It is not quite as developed but provides some of the finest primitive camping in the state with its large shade trees and sandy shorelines.



Figure 37. Cedar Bluff Reservoir Recreation Areas

4.3.1. Existing Conditions

4.3.1.1. Recreation Facilities and Visitation

The reservoir has 50 miles of shoreline and offers year-round fishing. The Bluffton Area provides a variety of facilities to meet the outdoor enthusiasts needs. The following list highlights the various recreational opportunities at Cedar Bluff (Cedar Bluff 2020 Annual Report):

Boat Ramps

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- Utility Campsites
- **Undesignated Primitive Sites Designated Primitive Sites**

- Group Campground Trail Systems
 - **Rental Cabins**
- In 2018, total visitation at Cedar Bluff Reservoir was 182,261. In addition, the KDWP is responsible for administering the contract for 104 private cabins that are located on USBR property. Cedar Bluff Wildlife Area has boat launching facilities, primitive camp sites, and shoreline fishing access. Visitation associated with use of the private cabins and the Cedar Bluff Wildlife Area are not included in the 2018 visitation estimates (USACE 2021. "Kansas River Reservoirs Flood and Sediment Study: USBR Reservoirs Cedar Bluff Data Request", August 21st 2021). iSportsman hunting data was not available for Cedar Bluff

Reservoir. The assessment assumed that 1% of total visitation (1,823 visits with full compliance) is hunting within wildlife areas, based on averages from other lakes. Additionally, 20% of that figure (365) accounts for wildlife viewing based on a USFWS report that provides state-wide hunting, fishing, and wildlife viewing trips in Kansas³ (USFWS, 2017).

Cedar Bluff State Park is host to numerous special events. The biggest event is the annual OK Kids Day event. Cedar Bluff State Park also hosts campout events for Boy Scouts, Girl Scouts and 4-H clubs, family reunions, weddings, school field trips, and several fishing tournaments. In the past Cedar Bluff State Park has also hosted several concerts and outdoor festivals (USACE 2021. "Kansas River Reservoirs Flood and Sediment Study: USBR Reservoirs Cedar Bluff Data Request" August 21st 2021).

4.3.1.2. Sport Fisheries

This section provides a summary of sport fishing at Cedar Bluff Reservoir. Additional information is provided in the Reservoir Fisheries Technical Report (see Appendix E). The general objective of fisheries management at Cedar Bluff Reservoir is to optimize the quality and diversity of angling opportunities. Specific management activities include tailoring fish harvest regulations to changes in sportfish population trends, stocking fish to enhance population abundance as needed, construction of fish attractors to enhance angling opportunities, and other activities for maintaining/improving angling access. While Cedar Bluff Reservoir does not have a lake level management plan, the reservoir tends to be managed using a simple approach of obtaining and retaining as much as water as possible for as long as possible.

Cedar Bluff Reservoir anglers tend to be non-specific in terms of the types of species they prefer, fishing for species that can be harvested. Angler preference for a specific species often varies based upon changes in the availability of species that are affected by surface water fluctuation, with anglers fishing for species that dominate the reservoir at the time they are fishing. The top sport fish, in order of harvest, based on the most recent creel surveys, are bass, crappie, and walleye. Other sport fish in the reservoir include bluegill, black bullhead, channel catfish, flathead catfish, green sunfish, smallmouth bass, spotted bass, and wiper (hybrid striped bass). Largemouth bass were highly preferred by anglers in the 2003 creel survey because refilling of the reservoir in the mid to late-1990's resulted in excellent black bass quality. Conversely, as the reservoir pool elevation declined through the 2000's and early 2010's, increased walleye recruitment promoted development of a population attractive to anglers. Regardless of the reservoir water level and relative sportfish population status, bass, crappie, and walleye are popular fisheries among Cedar Bluff Reservoir anglers in most years. Recent, lower rates of fish harvesting compared to historic levels are generally reflective of an increase in reservoir pool, which spreads out the existing fish population, resulting in reduced catch per unit effort (CPUE) by fishermen.

According to the most recent 2019 creel survey, total angler trips were estimated to be 26,008 (Appendix E). Angler effort (defined as angler-hours per acre) at Cedar Bluff often ranks in the 75 percentile or higher when compared to other Kansas reservoirs. Anglers typically come from western Kansas, with fishers from eastern Kansas and eastern Colorado frequenting the lake to a lesser degree.

Water inflows, drought conditions, sedimentation, and water quality impact angling preferences and fishing success. When past drought conditions have been accompanied by municipal requests to release water, the lake elevation has declined more quickly, which further decreases fish species reproduction when it has occurred in the past during the fish spawning season. Decreased fish reproduction in the past has negatively affected catch rates and total sport fishing catch. Historically, sedimentation caused docks to be silted in overtime at Cedar Bluff Reservoir, affecting angler access to the reservoir. Additionally, during low inflow conditions in the past, sedimentation has blocked inflows into the reservoir which

further decreases low pool elevations. When this has occurred during the spawning season it has resulted in reduced recruitment and reproduction, reducing future fish catch rates. However, there have been no major historic issues with sedimentation directly impacting fish habitat and angling at Cedar Bluff Reservoir. As Cedar Bluff Reservoir has a low maximum release rate for water, high inflow events tend to raise the level of the reservoir, flooding terrestrial vegetation and positively impacting fisheries and angling success rates in the following years. Finally, Cedar Bluff Reservoir generally possesses adequate water quality to provide sportfish habitat and survival, with low turbidity, although there are some localized areas of degraded water quality due to vegetation decomposition during warm water periods. In general, water quality conditions and sedimentation have had minimal impacts on sport fishing at Cedar Bluff Reservoir (USACE 2021. "Kansas River Reservoirs Flood and Sediment Study: USBR Reservoirs Meeting Notes" September 29, 2021).

4.3.1.3. Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

During the drought of 2006, the pool at Cedar Bluff Reservoir was down 15 feet (KDWP 2006). Cedar Bluff State Park staff have adapted to reoccurring drought conditions and have sought out new opportunities during low water conditions. As water levels fall, some boat ramps and beach areas become unusable. However, as the levels fall other boat ramps and beach areas become usable. Typically, the visitation to Cedar Bluff State Park mirrors the rise and fall of the water levels of the reservoir. As the lake rises, visitation is higher and vice versa (Cedar Bluff Data Request 8/21/20).

Cedar Bluff Reservoir began rising in late May of 2018 and throughout most of 2019. By the end of 2019 the reservoir had risen over 16 feet in elevation. When this rise in elevation began, Cedar Bluff Reservoir was almost 27 feet below top of multipurpose pool. Even with the rise in water level, the reservoirs elevation never approached flood pool. The visitation was higher over this time period (4% higher compared to 2018) because several other reservoirs in the state were flooding and were closed or partially closed to recreation. None of the recreational facilities were damaged in the rise of water levels at Cedar Bluff State Park. However, the shoreline access for fishing was limited due to the rise in elevation (Cedar Bluff Data Request 8/21/20).

Cedar Bluff State Park has not been impacted beyond minor localized effects by sediment issues (USACE 2021 ("Kansas River Reservoirs Flood and Sediment Study: USBR Reservoirs Meeting Notes" September 29, 2021).

Groundwater mining from the Ogallala Aquifer to supply water for agricultural irrigation, principally occurring from 1960 to 1980 has led to decreased flow in the Smoky Hill River Basin in Western Kansas (Buchanan et al., 1998). The reduced flow has resulted in a widely fluctuating reservoir pool. Reallocation of stored water in Cedar Bluff Reservoir has reduced water withdrawals such that evaporation and seepage are the two primary losses of water from the reservoir pool. These reductions in inflow combined with decreased discharge, results in a slow water level decline punctuated by periods of water level stability during most years. Net water level decline is generally the norm. However, cyclic periods of increased precipitation that occur approximately every 20 to 30 years, result in localized flooding that substantially increases reservoir pool elevation (Appendix E).

4.3.1.1. Critical Lake Elevations for Recreation

Lake elevations are an important factor for water- and shore-based recreation at Cedar Bluff Reservoir. Working with the KDWP fisheries experts, critical lake elevations for recreation were identified at Cedar Bluff Reservoir as well as the corresponding impacts to visitation. These lake elevations are used to qualitatively assess the impacts to visitation and economic benefits under FWOP conditions for Cedar Bluff Reservoir.

Lake Elevations	<2,095 ft	2,095-2,115 ft	2,115-2,125 ft	2,125-2,144; multi- purpose pool is 2,144 ft	2,144-2,155 ft	>2,155 ft
Visitation Impacts	1 boat ramp usable. Shoreline access dependent on road availability.	3-4 ramps useable. Shoreline access dependent on road availability.	4 boat ramps usable. Shoreline access dependent on road availability.	6-7 boat ramps usable. No shoreline access issues. Permanent infrastructure opportunities are maximized.	2 boat ramps available at the upper end of elevations. Shoreline access dependent on water inundation as levels increase.	No boat ramps available. Much of the permanent infrastructure is under water.
Quality of Recreation Effects	Boating access is very limited. Large expanses of sandy shoreline exposed. Aquatic habitat becomes limited while terrestrial wildlife and habitat acreage increases. Remaining water becomes more turbid.	Boating access decreases as ramps become unusable with decreasing water levels. Aquatic habitat continues to decrease. Terrestrial habitat and wildlife opportunities continue to increase due to falling water levels.	Access to shoreline dictated by availability of roads. Aquatic habitat is decreased. Terrestrial habitat opportunities increase.	Very little access issues. Recreation opportunities maximized between 2135 and 2144. Aquatic and terrestrial habitat ideal.	At lower elevations within this range, park recreation opportunities are maximized. Aquatic wildlife habitat increases. Terrestrial habitat decreases.	Most park facilities closed as infrastructure becomes inundated. Boat access severely limited due to ramps under water. Aquatic wildlife habitat increased. Terrestrial wildlife habitat decreased.

Table 115. Critical Lake Elevations for Recreation at Cedar Bluff Reservoir¹

¹ The information in this table was developed with input from KDWP staff familiar with Cedar Bluff Reservoir. Lake elevations are in NGVD 1929.

Table 116. Percent of Reservoir Impacted by Critical Lake Elevation Thresholds¹

Lake Elevations	<2,095 ft	2,095-2,115 ft	2,115-2,125 ft	2,125-2,144; multi- purpose pool is 2,144 ft	2,144-2,155 ft	>2,155 ft
Water-based Visitor Impacts	100%	75%	0%	50%	100%	100%
Shore-based Visitor Impacts	25%	20%	0%	25%	75%	100%

¹The information in this table was developed with input from KDWP staff familiar with Cedar Bluff Reservoir. Lake elevations are in NGVD 1929.

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4.3.2. Future Without Project Conditions

This section considers the impact of future conditions on recreation, including sediment, water surface elevations, water quality and fishery conditions. Qualitative methods only were used to assess the effects of harmful algal blooms, water quality issues, habitat availability, and changes to reservoir fisheries on recreation at reservoirs that were not modeled and assessed quantitatively. The information used to qualitatively assess recreation was based on research, documents (e.g., Kansas State Wildlife Action Plan), information from subject matter experts, and data generated prior to the study or during the study (e.g., projected sedimentation in reservoirs; assessments of reservoir fisheries).

Because USACE sediment modeling indicated very few impacts to future sediment conditions and because no H&H modeling was conducted for Cedar Bluff Reservoir, FWOP recreation impacts from sediment and changes in water surface elevations were evaluated qualitatively for this reservoir. Many of the western reservoirs do not have sufficient inflows for there to be notable sediment impacts.

4.3.2.1. Recreation Facilities and Visitation

KDWP will continue to operate and maintain the existing recreation facilities at Cedar Bluff Reservoir. Visitation during average water years will be similar to the visitation under baseline conditions (182,261 visitors annually). Special events will continue to be hosted at the reservoir similar to past special events.

Cedar Bluff Reservoir is expected to realize continued pool wide elevation fluctuations. Withdrawal of water from the Ogallala aquifer and Smoky Hill River alluvium for agricultural irrigation at current rates, and continued encroachment of phreatophyte species along the riparian corridors of the river and associated tributaries, will likely decrease baseflow and subsequent inflow into the reservoir. This will likely widen the amplitude of reservoir pool elevation fluctuation and promote the probability of extreme pool dewatering.

4.3.2.2. Sport Fisheries

At reduced pool, decreased water quality and reduced habitat availability and diversity, limit sportfish population abundance and welfare. When Cedar Bluff Reservoir is at low pool elevations, aquatic resource-based recreational opportunities available to the public, become more limited. During periods where water levels are higher in the multipurpose pool than on average shoreline access for fishing could be limited in the future similar to past example.

The stocking of intermediate-sized channel catfish will be continued in the future, if recent stockings reveal improvement of population abundance. Wiper fry will be stocked at a moderate rate, biannually, for the foreseeable future. Largemouth bass fingerlings will be stocked when trophic and habitat conditions resulting from substantial reservoir pool elevation increases occur.

The direction which angler use and visitation at Cedar Bluff takes is unclear, as changes in socioeconomic factors greatly influence public involvement in angling. For example, increased participation of families in youth sporting activities reduces participation in angling. However, the unforeseen emergence and response to COVID-19 in 2020 greatly increased public participation in angling and other outdoor recreation at Cedar Bluff Reservoir during the 2020 visitation season.

4.3.2.3. Effects of Sediment, Flooding, and Drought Conditions on Recreation

The effects of sediment on recreation at Cedar Bluff Reservoir will be similar to past conditions with only minor localized effects by sediment issues.

Similar to past droughts staff will adapt where possible and look for new opportunities for visitors to still recreate at the reservoir. In the future during drought conditions some boat ramps and beach areas could

become unusable but others may become usable. Visitation will reflect the rise and fall of the water levels with higher visitation as the reservoir rises and lower when the reservoir falls. With climate change these rise and falls could be more frequent and prolonged leading to longer effects to recreation in the future.

Cedar Bluff Reservoir typically is not at top of multipurpose pool and often not into the flood pool during flooding conditions. Visitors will often come to the reservoir when other reservoirs have limited access. This is expected to continue in the future at Cedar Bluff Reservoir. In 2018, the revenues associated with Cedar Bluff Reservoir were \$449,000.¹² At Cedar Bluff Reservoir in 2019, these revenues were \$582,00, an increase of 17% from 2018 revenues due to increased visitation from higher multipurpose pool elevations and flooding events in the region. With expected climate prediction of more frequent extreme flood events this may lead to more frequent rises in the multipurpose pool which could lead to more increases in visitation with the higher multipurpose pool levels.

During periods when the reservoir reaches the critical lake elevations for recreation the impacts (high and low) described in Table 115 and Table 116 to water-based and shore-based visitors are likely to occur with impacts to recreation leading to economic effects in the state and the region.

Water quality at Cedar Bluff Reservoir and expected future conditions related to water quality are included in Appendix G. Impairments associated with high phosphorus load and naturally occurring sulfate in the lake, naturally occurring metals, suspended solids and bacteria in the watershed will continue and potentially will decrease with the established TMDL. Climate is a fundamental driver of nutrient and sediment transport and expected future climate conditions will directly impact transport from land surface to streams and reservoirs.

5.0. Solomon-Republican Regional Planning Area

The Solomon-Republican Regional Planning Area (RPA) is in the northern-central part of the state. The RPA includes Keith Sebelius Lake (Prairie Dog State Park), Kirwin Reservoir, Lovewell Reservoir, Waconda Lake (Glen Elder Dam), and Webster Reservoir. All of these reservoirs are managed by USBR, and all reservoirs include state parks, managed by KDWP, except for Kirwin Reservoir, which is encompassed by the Kirwin National Wildlife Refuge, managed by the U.S. Fish and Wildlife Service (USFWS). Figure 38 outlines the Solomon-Republican Regional Planning Area and its reservoirs.

5.1. Keith Sebelius Reservoir (Norton Wildlife Area, Prairie Dog State Park)

Norton Wildlife Area, located 3 miles southwest of Norton, comprises Keith Sebelius Reservoir and adjacent lands except for the Prairie Dog State Park and Federal Operation Areas (Figure 39). Generally located from north to south, Prairie Dog State Park (Figure 40), the Keith Sebelius Reservoir, and then the Norton Wildlife Area are all part of the features in this area. Technically, Keith Sebelius Reservoir is part of the Norton Wildlife Area.

¹²These fees and revenues, generally paid by visitors to federal and state governments, are included in the estimate of economic output.



Figure 38. Solomon-Republican Regional Planning Area

5.1.1. Existing Conditions

5.1.1.1. Recreation Facilities and Visitation

In general, the lake offers water sports, picnicking, wildlife viewing, boating, fishing, camping, hiking, hunting, winter sports and RV access. The following recreational amenities are offered:

- Campsites
- Picnic Areas
- Cabins
- Boat Ramps
- Beach Area

Total visitation at Prairie Dog State Park in 2018 was 161,734, although this estimate does not include hunting trips visitation to Norton Wildlife Area. Approximately 65 % of the visitors participate in waterbased visitation, including boating, swimming, and angling, while 35% of visitors participate in shorebased activities, including camping, sight-seeing, and picnicking. The public lands manager at Keith Sebelius Reservoir estimates approximately 10,000 hunting and fishing visits to the lake annually. iSportsman hunting data isn't currently available for Keith Sebelius Reservoir. The study team assumed 1% of total visitation (1,617visits with full compliance) is hunting within wildlife areas, based on averages from other lakes. Additionally, it was assumed that 20% of that figure (323) accounts for



Figure 39. Keith Sebelius Reservoir Recreation Areas



Figure 40. Prairie Dog State Park

wildlife viewing based on a USFWS report that provides state-wide hunting, fishing, and wildlife viewing trips in Kansas³(USFWS, 2017). Special Events at Prairie Dog State Park include bass fishing tournaments approximately twice a month with about 10 boats, Carp Derby twice a year with around 200 fish harvested, archery shoots once a month all summer, and 5K walk/runs 3 times a year averaging about 50 participants. Weddings and reunions ranging from 50 to 250 guests happen about once a month throughout the summer. OK Kids Day draws 650 adults and kids. Other draws include high school and elementary field trips, kayak races, and Adobe home tours year-round.

5.1.1.2. Sport Fisheries

This section provides a summary of sport fishing at Keith Sebelius Reservoir. Additional information is provided in the Reservoir Fisheries Technical Report (see Appendix E). Fisheries management objectives are conducted to optimize the quality and diversity of angling opportunities through enhancement of population abundance as needed. Fisheries management measures include fish harvest regulations, fish attractors, stocking as needed, and sampling to monitor trends. Creel surveys for angler use and preferences support management of the fisheries. Fish species that inhabit Keith Sebelius Reservoir have periods where changes in abundance and shifts in sportfish species dominance occur from conditions that affect habitat quantity and quality (Appendix E).

Keith Sebelius anglers tend to be non-specific in terms of the types of species they prefer, with 48% saying they have no fish preference (KDWP 2016). The top sport fish, in order of harvest, based on the most recent creel surveys is saugeye and wiper. Other sportfish at Keith Sebelius Reservoir include crappie, largemouth bass, channel catfish, flathead catfish, bluegill, black bullhead, green sunfish, smallmouth bass, and walleye (Appendix E). According to the last creel survey in 2016, the number of angler trips were estimated to be 15,950 (KDWP 2016). Typically, saugeye is mainly targeted by anglers in the spring and early summer, usually drawing big crowds. However, at Keith Sebelius Reservoir it appears that anglers are targeting them all year long and are the second most sought after species. Spotted bass along with the largemouth bass are a highly sought-after species at Keith Sebelius Reservoir. Thus, drawing a lot of bass club tournaments from all over Kansas and the surrounding states. Spotted bass numbers have steadily declined the last five years due to the water clarity during sampling and their ability to avoid sampling techniques. The third most sought-after species is the wiper. Wiper numbers are typically relatively stable, and anglers are pretty good at catching them. Channel catfish, flathead catfish, black crappie, and white crappie are usually in the top four species that anglers target at Keith Sebelius Reservoir.

5.1.1.3. Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

In 2006, Kansas and other neighboring states experienced a severe drought. Reservoir storage in the multipurpose pool at Keith Sebelius Reservoir was very low. A minimum pool agreement with the local irrigation district kept the pool from going completely dry but the pool elevation was 18 feet below conservation pool (KDWP 2006).

Again in 2012, drought conditions caused the water level to decrease due to increased irrigation usage from the reservoir; the reservoir ranged from six to 10 feet below conservation pool. Visitation slowly decreased throughout the drought period as fishing and boating also decreased. According to an economic report written in 2018, the reservoir experienced droughts in 2011, 2012 and 2013. In January of 2013 the conservation pool was 48.1% full (KWO 2018).

While reservoir elevations at Keith Sebelius Reservoir are typically below top of multipurpose pool during years with high water conditions higher reservoir elevations can greatly increase recreational use and visitation. Keith Sebelius Reservoir increased about 8 feet in 2019 when the reservoir was about 12

feet below conservation pool at the time. According to USBR data, 2019 revenue was 25% higher than 2018, while visitation increased by 1% (KDWP 2018-2019).

Sedimentation within the reservoir has not had any noticeable effect on use or operations at the reservoir. There have not been any management actions needed to address issues associated with sediment.

Keith Sebelius Reservoir has had a HAB every year since blooms were first recorded in 2014 at the reservoir. The blooms usually last about three or four weeks and occur during June and July. Recreation and visitation doesn't decrease much during HAB blooms; however, the beach is often closed to swimming and angling if the blooms become denser. In 2019 there was a watch in July and a warning in June, and there was a corresponding decrease in visitation in June compared to years without a HAB event.

5.1.1.4. Critical Lake Elevations for Recreation

Lake elevations are an important factor for water- and shore-based recreation at Keith Sebelius Reservoir. Working with the KDWP fisheries experts, critical lake elevations for recreation were identified at Keith Sebelius Reservoir as well as the corresponding impacts to visitation. These lake elevations are used to qualitatively assess the impacts to visitation and economic benefits under FWOP conditions for Keith Sebelius Reservoir.

Lake Elevations	<2,775 ft	2,775-2,280 ft	2,280-2,304; multi-purpose pool is 2,304.3 ft	2,304-2,331 ft	2,331-2,341 ft	>2,341 ft
Visitation Impacts	There is no boating or water-based access; other shore visitation is decreased from lack of water access.	25% of boating access is available, all other recreation largely unaffected.	No access issues.	80% of boating access is available; all other uses are largely unaffected.	No boat ramps accessible; 75% of lake shore access closed.	All recreation is closed at the lake.
Quality of Recreation Effects	Aesthetic values decrease dramatically as exposed shorelines grow. Boating safety is a high concern for all visitors due to increase of unmarked underwater hazards.	Safety becomes an issue for remaining boaters; hazards begin to surface.	No impacts	No impacts	Safety becomes an issue for remaining visitors.	Closed

¹ The information in this table was developed with input from KDWP staff familiar with Keith Sebelius Reservoir. Lake elevations are in NGVD 1929.

Table 118. Percent of Reservoir Impacted by Critical Lake Elevation Thresholds

Lake Elevations	<2,775 ft	2,775-2,280 ft	2,280-2,304; multi-purpose pool is 2,304.3 ft	2,304-2,331 ft	2,331-2,341 ft	>2,341 ft
Water-based Visitor Impacts	100%	75%	0%	50%	100%	100%
Shore-based Visitor Impacts	25%	20%	0%	25%	75%	100%

The information in this table was developed with input from KDWP staff familiar with Keith Sebelius Reservoir. Lake elevations are in NGVD 1929.

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5.1.1. Future Without Project Conditions

This section considers the impact of future conditions on recreation, including sediment, water surface elevations, water quality and fishery conditions. Qualitative methods only were used to assess the effects of harmful algal blooms, water quality issues, habitat availability, and changes to reservoir fisheries on recreation at reservoirs that were not modeled and assessed quantitatively. The information used to qualitatively assess recreation was based on research, documents (e.g., Kansas State Wildlife Action Plan), information from subject matter experts, and data generated prior to the study or during the study (e.g., projected sedimentation in reservoirs; assessments of reservoir fisheries). Because USACE sediment modeling indicated very few impacts to future sediment conditions and because no H&H modeling was conducted for Keith Sebelius Reservoir, FWOP recreation impacts from sediment and changes in water surface elevations were evaluated qualitatively for this reservoir. Many of the western reservoirs do not have sufficient inflows for there to be notable sediment impacts.

5.1.1.1. Recreation Facilities and Visitation

Keith Sebelius Reservoir is authorized and operated to include irrigation storage. If irrigation withdrawals continue the reservoir will continue to see wide fluctuations in the amount of water it contains. Typically, the reservoir elevation drops at least three to four feet each year for irrigation if enough water is in the reservoir for the irrigation district to use. It is not unusual for the reservoir to be 15 to 20 feet below conservation pool and has been down around 30 feet a few different times since construction.

When Keith Sebelius Reservoir is at low pool elevations, aquatic resource – based recreational opportunities available to the public, become more limited. This trend is expected to continue in the future with impacts to the reservoir and to reservoir fisheries occurring when the reservoir is at low pool elevations either from lack of inflows, lowering of conservation pool during irrigation releases, and a combination of the two. KDWP will continue to operate and maintain the existing recreation facilities at Keith Sebelius Reservoir. Visitation during average water years will be similar to the visitation under baseline conditions (161,734 visitors annually). Special events will continue to be hosted at the reservoir similar to past special events.

5.1.1.2. Sport Fisheries

Fisheries management objectives will continue to optimize the quality and diversity of angling opportunities through enhancement of population abundance as needed. Fisheries management measures will continue to include fish harvest regulations, fish attractors, stocking as needed, and sampling to monitor trends. Creel surveys for angler use and preferences will also continue to support management of the fisheries. Fish species that inhabit Keith Sebelius Reservoir are not expected to change in the future but will have periods where changes in abundance and shifts in sportfish species dominance occur from conditions that affect habitat quantity and quality, similar to what is now experienced at Keith Sebelius Reservoir.

Fisheries management objectives will continue to optimize the quality and diversity of angling opportunities through enhancement of population abundance as needed. Fisheries management measures will continue into the future to include fish harvest regulations, fish attractors, stocking as needed, and sampling to monitor trends. Creel surveys for angler use and preferences will also continue to support management of the fisheries. Fish species that inhabit Keith Sebelius Reservoir are not expected to change in the future but will have periods where changes in abundance and shifts in sportfish species dominance occur from conditions that affect habitat quantity and quality, similar to what is now experienced at Keith Sebelius Reservoir (Appendix E). At reduced pool elevations, decreased water quality and reduced habitat availability and diversity limit sportfish population abundance and welfare.

While sedimentation will continue to occur (9.2% loss of the multipurpose over the next 50 years) it is not expected to create impacts to reservoir fisheries or their habitat in the future. If the invasive species Phragmites increases at Keith Sebelius Reservoir there could be issues related to reservoir fisheries unable to access habitat (e.g., shorelines, coves) in the future. Fisheries management objectives will continue to optimize the quality and diversity of angling opportunities through enhancement of population abundance as needed. Fish species that inhabit Keith Sebelius Reservoir are not expected to change in the future but will have periods where changes in abundance and shifts in sportfish species dominance occur from conditions that affect habitat quantity and quality, similar to what is now experienced at Keith Sebelius Reservoir.

5.1.1.3. Effects of Sediment, Flooding, and Drought Conditions on Recreation

While sedimentation will continue to occur (9.2% loss of the MP over the next 50 years) the effects of sediment on recreation at Keith Sebelius Reservoir will be similar to past conditions with only minor localized effects by sediment issues.

Similar to past droughts water levels will decrease due to increased irrigation usage causing visitation to slowly decrease during drought periods and fishing and boating will decrease. With climate change these decreases in visitation could be more frequent and prolonged leading to longer effects to recreation in the future.

Keith Sebelius Reservoir typically is not at top of multipurpose pool and often not into the flood pool during flooding conditions. Visitors will often come to the reservoir when other reservoirs have limited access. This is expected to continue in the future at Keith Sebelius Reservoir. In 2018, the revenues associated with Keith Sebelius Reservoir were \$201,124.¹³ At Cedar Bluff Reservoir in 2019, these revenues were \$245,436, an increase of 18% from 2018 revenues due to increased visitation from higher multipurpose pool elevations and flooding events in the region. With expected climate prediction of more frequent extreme flood events this may lead to more frequent rises in the multipurpose pool which could lead to more increases in visitation with the higher multipurpose pool levels.

During periods when the reservoir reaches the critical lake elevations for recreation the impacts (high and low) described in Table 117 and Table 118 to water-based and shore-based visitors are likely to occur with impacts to recreation leading to economic effects in the state and the region.

Water quality at Keith Sebelius Reservoir and expected future conditions related to water quality are included in Appendix G. Impairments associated with high phosphorus load and naturally occurring arsenic in the watershed will continue and potentially will decrease with the established TMDL. HAB will continue in the future from cyanobacteria blooms causing potential warnings during the recreation season. Climate is a fundamental driver of nutrient and sediment transport and expected future climate conditions will directly impact transport from land surface to streams and reservoirs.

¹³These fees and revenues, generally paid by visitors to federal and state governments, are included in the estimate of economic output.

5.2. Kirwin Reservoir

Kirwin Reservoir is located 4 miles west and one mile south of Kirwin, Kansas, and 11 miles southeast of Phillipsburg, Kansas. Kirwin National Wildlife Refuge surrounds Kirwin Reservoir; it was created as the first wildlife refuge in Kansas (est. 1954). It offers year-round fishing, in addition to winter sports, boating, hunting and wildlife viewing. Kirwin Reservoir is managed by the USBR. The Kirwin National Wildlife Refuge was established as an overlay project on the irrigation and flood control reservoir. U.S. Fish and Wildlife refuge staff manage all activities on the reservoir and its surrounding lands, except for irrigation and flood control. The primary purpose of the Kirwin NWR is to provide nesting cover, food and shelter for songbirds, waterfowl, upland game birds, and mammals. The Kirwin National Wildlife Refuge is displayed in Figure 41.

5.2.1. Existing Conditions

5.2.1.1. Recreation Facilities and Visitation

There are three picnic areas and three boat ramps at Kirwin National Wildlife Refuge. In 2017, total visitation was 134,309. Fishing activity alone accounted for 40,000 recreation visits, and boating accounted for 5,500 visits. (USFWS, 2017). Hunting is allowed for legal refuge species in locations surrounding the reservoir.

5.2.1.2. Sport Fisheries

This section provides a summary of sport fishing at Kirwin Reservoir. Additional information is provided in the Reservoir Fisheries Technical Report (see Appendix E). The general objective of fisheries management at Kirwin Reservoir is to optimize fishing opportunities by maintaining fish populations (Appendix E). Specific management activities include tailoring fish harvest regulations to changes in sportfish population trends, stocking fish to enhance population abundance as needed, construction of fish attractors to enhance angling opportunities, and other activities for maintaining/improving angling access.



Figure 41. Kirwin Reservoir National Wildlife Refuge

Kirwin Reservoir has within its pool allocations a component for irrigation withdrawals that can create wide fluctuations in water levels. Typically, the reservoir elevation drops at least 4 to 5 feet each year for irrigation if enough water is in the reservoir for the irrigation district to use. Recent years have been wetter than normal, however, when it gets dry the reservoir tends to take a downward trend in elevation due to the cumulation of an irrigation release and the lack of water coming into the reservoir. At reduced pool elevations, decreased water quality and reduced habitat availability and diversity limit sportfish population abundance and welfare. When Kirwin Reservoir is at low pool elevations, aquatic resource – based recreational opportunities available to the public, become more limited. This trend is expected to continue in the future with impacts to the reservoir and to reservoir fisheries occurring when the reservoir is at low pool elevations either from lack of inflows, lowering of conservation pool during irrigation releases, and a combination of the two (Appendix E).

Kirwin Reservoir anglers tend to be pretty specific in terms of the types of species they prefer. According to 2018 creel results 84% of anglers had a preferred species (KDWP 2018). According to the most recent

creel survey done in 2018 there were approximately 10,178 anglers at Kirwin Reservoir (KDWP 2018). The top sport fish, in order of harvest is white bass. Other sportfish at Kirwin Reservoir include crappie, largemouth bass, channel catfish, flathead catfish, bluegill, black bullhead, green sunfish, and walleye (Appendix E). White bass numbers are typically relatively stable, and anglers are pretty good at catching them. The second most sought after species are channel and flathead catfish. Their numbers typically stay relatively consistent, however, the population does better when the water elevations remain higher. Black and white crappie are also a popular species at Kirwin Reservoir but the population is rather cyclical due to the reoccurring lowering of water levels for irrigation needs. Walleye and largemouth bass fishing also draws large numbers of anglers at the reservoir most of the year. Largemouth bass population numbers and angling success can be affected by low water elevations.

If the invasive species Phragmites increases at Kirwin Reservoir there could be issues related to reservoir fisheries unable to access habitat (e.g., shorelines, coves) in the future.

5.2.1.3. Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

Kirwin Reservoir has not been impacted by sediment with only localized sediment occurring causing minor impacts to recreation.

Irrigation releases from Kirwin Reservoir typically start in middle June and are not shut off until late August. Typically, the North Fork Solomon River and Bow Creek do not flow enough water to keep up with irrigation releases. As discussed under sportfish during drought conditions the reservoir tends to take a downward trend in elevation due to the cumulation of an irrigation release and the lack of water coming into the reservoir. It is not unusual for the reservoir to be 15 to 20 feet below multipurpose pool and it has been down around 30 feet a few different times since construction. Once the reservoir gets this low it usually takes a significant rain event or series of events to get it back up to multipurpose pool. During the drought of 2006 Kirwin Reservoir was 23.9 feet below conservation pool (KDWP 2006). The area experienced additional droughts in 2012 and 2013. In January of 2013 the conservation pool at Kirwin was 68.1% full (KWO 2013).

5.2.1.1. Critical Lake Elevations for Recreation

Critical lake elevations for recreation were not available for Kirwin Reservoir. The impacts to visitation and economic benefits under FWOP conditions for Kirwin Reservoir were assessed qualitatively using information from past years when conditions created impacts to recreation.

5.2.1. Future Without Project Conditions

This section considers the impact of future conditions on recreation, including sediment, water surface elevations, water quality and fishery conditions. Qualitative methods only were used to assess the effects of harmful algal blooms, water quality issues, habitat availability, and changes to reservoir fisheries on recreation at reservoirs that were not modeled and assessed quantitatively. The information used to qualitatively assess recreation was based on research, documents (e.g., Kansas State Wildlife Action Plan), information from subject matter experts, and data generated prior to the study or during the study (e.g., projected sedimentation in reservoirs; assessments of reservoir fisheries).

Because USACE sediment modeling indicated very few impacts to future sediment conditions and because no H&H modeling was conducted for Kirwin Reservoir, FWOP recreation impacts from sediment and changes in water surface elevations were evaluated qualitatively for this reservoir. Many of the western reservoirs do not have sufficient inflows for there to be notable sediment impacts.

5.2.1.1. Recreation Facilities and Visitation

Kirwin Reservoir is authorized and operated to include irrigation storage.. If irrigation withdrawals continue the reservoir will continue to see wide fluctuations in the amount of water it contains. Typically, the reservoir elevation drops at least three to five feet each year for irrigation if enough water is in the reservoir for the irrigation district to use. There are typically no issues related to access for water and shore-based recreation from these drops.

When Kirwin Reservoir drops to lower pool elevations, aquatic resource – based recreational opportunities available to the public, become more limited. This trend is expected to continue in the future with impacts to the reservoir and to reservoir fisheries occurring when the reservoir is at low pool elevations either from lack of inflows, lowering of multipurpose pool during irrigation releases, and a combination of the two.

KDWP and USFWS will continue to operate and maintain the existing recreation facilities at Kirwin Reservoir. Visitation during average water years will be similar to the visitation under baseline conditions (134,309 visitors annually).

5.2.1.2. Sport Fisheries

Fisheries management objectives will continue to optimize the quality and diversity of angling opportunities through enhancement of population abundance as needed. Fisheries management measures will continue to include tailoring fish harvest regulations to changes in sportfish population trends, stocking fish to enhance population abundance as needed, construction of fish attractors to enhance angling opportunities, and other activities for maintaining/improving angling access. Creel surveys for angler use and preferences will also continue to support management of the fisheries. Fish species that inhabit Kirwin Reservoir are not expected to change in the future but will have periods where changes in abundance and shifts in sportfish species dominance occur from conditions that affect habitat quantity and quality, similar to what is now experienced at Kirwin Reservoir (Appendix E).

While sedimentation will continue to occur (2.4% loss of the multipurpose over the next 50 years) it is not expected to create impacts to reservoir fisheries or their habitat in the future. If the invasive species Phragmites increases at Keith Sebelius Reservoir there could be issues related to reservoir fisheries unable to access habitat (e.g., shorelines, coves) in the future.

5.2.1.3. Effects of Sediment, Flooding, and Drought Conditions on Recreation

The effects of sediment on recreation at Kirwin Reservoir will be similar to past conditions with only minor localized effects by sediment issues.

In the future during drought conditions boating access could become limited and visitation for shorebased recreation would decrease from the lack of water access. Safety concerns for boaters also become an issue during drought and lower multipurpose pool elevations from unmarked underwater hazards. Extreme drops in water elevation in the multipurpose pool are likely to occur in the future and may be as low as 15 to 20 feet below top of multipurpose pool or as low as 30 feet below similar to past conditions during drought. When these conditions occur, there is no boating access and shore-based visitation is reduced. Aesthetic values also could decrease dramatically as exposed shorelines grow. Visitation will reflect the rise and fall of the water levels with higher visitation as the reservoir rises and lower when the reservoir falls. With climate change these rise and falls could be more frequent and prolonged leading to longer effects to recreation in the future.

Kirwin Reservoir typically is not at top of multipurpose pool and often not into the flood pool during flooding conditions. With expected climate prediction of more frequent extreme flood events this may

lead to more frequent rises in the multipurpose pool which could lead to more increases in visitation with the higher multipurpose pool levels.

During periods when the reservoir reaches the critical lake elevations for recreation the impacts (high and low) to water-based and shore-based visitors are likely to occur with impacts to recreation leading to economic effects in the state and the region.

Water quality at Kirwin Reservoir and expected future conditions related to water quality are included in Appendix G. Impairments to Kirwin Reservoir and the Upper North Fork Solomon River are associated with nutrients and naturally occurring selenium in the watershed will continue and potentially will decrease with the established TMDL. Climate is a fundamental driver of nutrient and sediment transport and expected future climate conditions will directly impact transport from land surface to streams and reservoirs.

5.3. Lovewell Reservoir

Lovewell State Park, surrounding Lovewell Reservoir, is in northcentral Kansas. Located 18 miles northeast of Mankato on US Hwy. 14, Lovewell is 6.4 miles south of the Nebraska/Kansas state line (Figure 42).

5.3.1. Existing Conditions

5.3.1.1. Recreation Facilities and Visitation

The reservoir offers boating, fishing (year-round), water sports, wildlife viewing, RV access, picnicking and hunting (recreation.gov). With 44 miles of shoreline, Lovewell State Park hosts the following recreational amenities (2020 Lake Report):

- Archery Range
- Disc Golf Course
- Beach
- Camping Cabins
- Campgrounds

- Campsites
- RV hookups
- Mobile Home Site
- Picnic Area
- Boat Ramps

The reservoir does host some annual events like the Lovewell Reservoir fun day in August, a campground Christmas (in August), a lake fireworks display, and a 3D archery shoot both in September.

In 2018, annual visitation to Lovewell Reservoir was 251,975 visitors. Approximately 65% of the visitors participated in water-based activities (swimming, angling, and boating) while 35% participated in shore-based activities. Approximately 65,000 additional visitors are associated with the Private Cabin Permit area. According to 2018 iSportsman data 0.5% of total visitation (1,261 visits with full compliance) is hunting within wildlife areas. Additionally, it is assumed that 20% of that number (252) accounts for wildlife viewing based on a USFWS report that provides state-wide hunting, fishing, and wildlife viewing trips in Kansas³ (USFWS, 2017).



Figure 42. Lovewell Reservoir Recreation Areas

5.3.1.2. Sport Fisheries

This section provides a summary of sport fishing at Lovewell Reservoir. Additional information is provided in the Reservoir Fisheries Technical Report (see Appendix E). The general objective of fisheries management at Lovewell Reservoir is to optimize the quality and diversity of angling opportunities. Specific management activities conducted include tailoring fish harvest regulations to changes in sportfish

population trends, stocking fish to enhance population abundance as needed, construct fish attractors to enhance angler success, and maintain/improve angling access (Appendix E).

Angler effort (angler-hours/acre) at Lovewell Reservoir ranks anywhere from the 25th to the 75th% when compared to other Kansas reservoirs depending on the year. Anglers hailing from the surrounding communities and Nebraska exert most of the pressure, with fishers from eastern Kansas and south-central Kansas frequenting the lake to a lesser degree (Appendix E). Lovewell Reservoir anglers tend to be opportunistic in terms of species they prefer to fish for. Angler preference for a specific species often varies based upon changes in species dominance that result from water fluctuation history or recent recruitment. For example, no preference has been the most popular response when anglers are asked what they are fishing for in two of the past four surveys. The strong walleye population had anglers respond with that species most often in 2005 but walleve have declined to second during the past three surveys. Channel catfish are always found in the top four, ranging from first in 2011 to fourth in 2006 and 2015, depending on other opportunities. White bass are also a critical species for anglers and were in the top three during 75% of the surveys. Crappie numbers fluctuate more than most species and angler effort toward them is highly variable with this species only showing up in 2005. Many of the no preference anglers are likely "crappie fishing" but are happy to catch anything. The indiscriminate selection of target species has become more prominent as well with many anglers less focused on one species but rather preferring a mixed bag or taking advantage of whatever species is most readily available at the time. Lovewell Reservoir anglers tend to be harvest minded. White bass, channel catfish, and crappie comprise the largest contributions to angler's creel in most years.

The population dynamics of black crappie, bluegill, and white crappie have fluctuated based upon reservoir level history as recruitment is generally stable at a low level or during stable or declining water levels. However, there is a positive correlation between recruitment and reservoir level. Increased reservoir pool elevation will likely improve recruitment conditions that should increase abundance of black crappie, bluegill, and white crappie in the future. Lovewell Reservoir traditionally has a strong channel catfish population due to the high numbers of gizzard shad, abundant spawning and brood rearing areas, and relatively low angling pressure compared to other reservoirs. Channel catfish numbers have steadily increased since a low in 2014. Numerous upstream sources have likely contributed to the largemouth bass population, which is typically a low density, high quality population. Due to the annual water level fluctuations, habitat needed for proper largemouth bass recruitment and survival is limited and the population has never reached a desired number. Natural reproduction has not been sufficient to maintain a strong population of walleye, thus supplemental stocking is frequently utilized. Anglers will continue to realize a limited walleye population characterized by poor to fair recruitment but excellent growth rates. The future of walleve in Lovewell Reservoir is precarious and saugeve may be the better option given the habitat conditions and their ability to not flush from reservoirs during high release events. The white bass population has been good to very good over the past 15 to 20 years but the latest sample illustrated their numbers had declined. Lovewell dropped from 8th to 20th among the state's reservoirs for white bass density and is ranked 19th for preferred fish. Wiper are a hybrid species requiring stocking on a regular basis to maintain population abundance. They have existed at a lowdensity population and supplement the white bass fishery by providing larger, trophy fish while also helping to control the gizzard shad population. Despite extensive stocking of fry and fingerlings, their numbers have never been extremely high as is the case in other Kansas reservoirs.

5.3.1.3. Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

During flood events, water levels have reached over seven feet above the top of the multipurpose pool four times including 1589.8 feet NGVD 29 in 1987, 1590.7 feet NGVD 29 in 1974, 1591.6 feet NGVD

29in 1993, and the highest recorded level was 1593.0 feet NGVD 29 in 2019, 10.4 feet above conservation. Flooding in the summer of 2019 caused impacts for recreation, limiting access to the lake and recreational activities and causing HABs. Visitation was 11% lower in 2019 compared to 2018 (KDWP 2018-2019). Vehicle revenues were down 10% overall, however daily vehicle permit sales were down over 20%, mostly due to the flooded conditions in 2019 and lack of access to day use areas for the summer season. Camping revenues were also down in 2019. This also has a direct effect on state park visitation and the economy surrounding the reservoir. Special Event permit revenues decreased approximately 30% compared to recent years, due to the flooding conditions.

Because water can be diverted from the Republican River, Lovewell Reservoir does not experience longterm drought conditions like other reservoirs in the area. The area suffered a drought in 2012 and 2013; the conservation pool was 67.3% full in January of 2013 although recreational access was not affected. Lovewell Reservoir has not had sedimentation issues that affect recreation.

HABs are occasionally an issue at Lovewell Reservoir. In 2015 there were three warnings in June and July, and in 2019 there were two in July and August. These warnings seemed to have more of an impact on visitation in 2015, corresponding to a 9% and 66% decrease in visitation compared to averages during June and July respectively. No monthly decrease in visitation was observed during the HAB warnings in 2019.

Lovewell Reservoir is expected to continue a similar water level fluctuation pattern soon as irrigation to meet farmland requirements both above and below the reservoir remains of upmost importance. At reduced pool, decreased water quality and reduced habitat availability and diversity limit sportfish population abundance and welfare. When Lovewell Reservoir is at low pool elevations, aquatic resource-based recreational opportunities available to the public become more limited.

5.3.1.4. Critical Lake Elevations for Recreation

Lake elevations are an important factor for water- and shore-based recreation at Lovewell Reservoir. Working with the KDWP fisheries experts, critical lake elevations for recreation were identified at Lovewell Reservoir as well as the corresponding impacts to visitation. These lake elevations are used to qualitatively assess the impacts to visitation and economic benefits under FWOP conditions for Lovewell Reservoir.

5.3.1. Future Without Project Conditions

This section considers the impact of future conditions on recreation, including sediment, water surface elevations, water quality and fishery conditions. Qualitative methods only were used to assess the effects of harmful algal blooms, water quality issues, habitat availability, and changes to reservoir fisheries on recreation at reservoirs that were not modeled and assessed quantitatively. The information used to qualitatively assess recreation was based on research, documents (e.g., Kansas State Wildlife Action Plan), information from subject matter experts, and data generated prior to the study or during the study (e.g., projected sedimentation in reservoirs; assessments of reservoir fisheries).

Because USACE sediment modeling indicated very few impacts to future sediment conditions and because no H&H modeling was conducted for Lovewell Reservoir, FWOP recreation impacts from sediment and changes in water surface elevations were evaluated qualitatively for this reservoir.

Lake Elevations	<1,571.7 ft	1,571.7-1,582.6 ft	1,582.6- 1584.1; multi- purpose pool is 1,582.6 ft	1,584.1-1,589.1 ft	1,589.1-1,595.3 ft	>1,595.3 ft
Visitation Impacts	There is limited to no boating or water- based access; other shore visitation is decreased from lack of water access.	25% of boating access is available; all other recreation largely unaffected.	No access issues.	100% of boating access is available; all other uses are largely unaffected.	No boat ramps accessible; 75% of lake shore access closed.	All recreation is closed at the lake.
Quality of Recreation Effects	Aesthetic values decrease dramatically as exposed shorelines grow. Boating safety is a high concern for all visitors due to increase of unmarked underwater hazards.	Safety becomes an issue for remaining boaters; hazards begin to surface.	No impacts	No impacts	Safety becomes an issue for remaining visitors.	Closed

Table 119. Critical Lake Elevations for Recreation at Lovewell Reservoir¹

¹ The information in this table was developed with input from KDWP staff familiar with Lovewell Reservoir. Lake elevations are in NGVD 1929.

Table 120. Percent of Reservoir Impacted by Critical Lake Elevation Thresholds

Lake Elevations	<1,571.7 ft	1,571.7-1,582.6 ft	1,582.6- 1584.1; multi- purpose pool is 1,582.6 ft	1,584.1-1,589.1 ft	1,589.1-1,595.3 ft	>1,595.3 ft
Water-based Visitor Impacts	100%	75%	0%	50%	100%	100%
Shore-based Visitor Impacts	25%	20%	0%	25%	75%	100%

¹ The information in this table was developed with input from KDWP staff familiar with Lovewell Reservoir. Lake elevations are in NGVD 1929

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5.3.1.1. Recreation Facilities and Visitation

KDWP will continue to operate and maintain the existing recreation facilities at Lovewell Reservoir. Visitation during average water years will be similar to the visitation under baseline conditions (251,975 visitors annually). Special events will continue to be hosted at the reservoir similar to past special events.

Lovewell Reservoir is expected to continue a similar water level fluctuation pattern as irrigation to meet farmland requirements both above and below the reservoir will remain of upmost importance. Changes are being made to improve the efficiency of the water delivery system which should take some strain off the water volume requirements. Other discussions have been ongoing regarding future alternatives to water storage including raising the conservation pool of Lovewell Reservoir to increase water volume or construction of another reservoir in the area for additional water storage. These options continue to be discussed but no decisions have been finalized. When Lovewell Reservoir is at low pool elevations, aquatic resource-based recreational opportunities available to the public become more limited.

5.3.1.2. Sport Fisheries

At reduced pool, decreased water quality and reduced habitat availability and diversity limit sportfish population abundance and welfare. The stocking of fry, fingerling, and intermediate-sized walleye will continue annually to boost recruitment and supplement the limited natural reproduction which occurs. Blue catfish were stocked for five years but are now set to expand with natural reproduction and will not be stocked again. Wiper fry, fingerlings, and intermediates are also stocked annually to maintain this aggressive predator. Saugeye are thought to have the potential to recruit, grow, and survive in Lovewell Reservoir compared with their walleye cousins and may be stocked in the future. With Milford Reservoir downstream containing a viable walleye population, special care must be considered before adding a new species to the watershed. This potential new stocking will continue to be evaluated and ideally a solution that can improve the Lovewell Reservoir fishery while also maintaining the Milford Reservoir fishery can be agreed upon.

The direction which angler use and visitation at Lovewell Reservoir takes is unclear, as changes in socioeconomic factors greatly influence public involvement in angling. For example, increased participation of families in youth sporting activities reduces participation in angling. However, the unforeseen emergence and response to COVID-19 greatly increased public participation in angling and other outdoor recreation at Lovewell Reservoir during the 2020 season.

5.3.1.3. Effects of Sediment, Flooding, and Drought Conditions on Recreation

The effects of sediment on recreation at Lovewell Reservoir will be similar to past conditions with only minor localized effects by sediment issues. Sediment will continue to accumulate in Lovewell Reservoir with an expected additional 2.2 % loss of the multipurpose pool over the next 25 years (2049) and 4.1% loss over the next 50 years (2074) (Appendix D).

While Lovewell Reservoir typically does not experience long-term drought conditions similar to past droughts water levels will decrease due to increased irrigation usage causing visitation to slowly decrease during drought periods and fishing and boating could decrease. Impacts to recreation can occur when reservoir elevations are below top of multipurpose pool with reduced boating access and limited water recreation and limited to no boating access when elevations are 17 feet below top of multipurpose pool. Safety also becomes an issue during these conditions from underwater hazards. With climate change these decreases in visitation could be more frequent and prolonged leading to longer effects to recreation in the future.
Lovewell Reservoir has experienced impacts during past flooding events with higher pool elevations that caused impacts to recreation and damages to recreation infrastructure. These impacts are expected to continue in the future at Lovewell Reservoir during high flood pool conditions. Impacts from reduced access for boating and shore-based recreation start at approximately seven feet above top of multipurpose pool and above 1595.3 feet NGVD 29all recreation is closed at the reservoir. In 2018, the revenues associated with Lovewell Reservoir were \$565,400.¹⁴ At Lovewell Reservoir in 2019, these revenues were \$567,400, an increase of less than one percent from 2018 revenues. During periods when the reservoir reaches the critical lake elevations for recreation the impacts (high and low) described in Table 119 and Table 120 to water-based and shore-based visitors are likely to occur with impacts to recreation leading to economic effects in the state and the region. With expected climate prediction of more frequent extreme flood events this may lead to more frequent impacts to recreation and damages to recreation infrastructure.

Water quality at Lovewell Reservoir and expected future conditions related to water quality are included in Appendix G. Impairments associated with high phosphorus load and naturally occurring arsenic and selenium in the watershed will continue and potentially will decrease with the established TMDL. HAB will continue in the future from cyanobacteria blooms causing potential warnings during the recreation season. Climate is a fundamental driver of nutrient and sediment transport and expected future climate conditions will directly impact transport from land surface to streams and reservoirs.

5.4. Waconda Reservoir

Waconda Reservoir and State Park is located one mile west of Glen Elder, Kansas near highway US 24 (Figure 43). The lake was built in 1968 for irrigation, flood control, and recreation. Because the irrigation district below the reservoir was never fully established, the demand for water for irrigation is lower than other western Kansas lakes, and the water level has historically remained relatively stable. Waconda Reservoir has 100 miles of shoreline; Glen Elder State Park is located on the northeastern shore of Waconda Reservoir. Glen Elder Wildlife Area encompasses almost 13,200 land acres surrounding the lake. The reservoirs, state park, and wildlife area offer numerous recreational amenities such as boating, camping, fishing, hunting, picnicking, RV access, water sports and wildlife viewing.

5.4.1. Existing Conditions

5.4.1.1. Recreation Facilities and Visitation

Glen Elder State Park/Waconda Reservoir includes the following recreational amenities:

Utility Campsites

Boat Ramps

Primitive Campsites

- Cabins
- Annual visitation at the State Park was 201,962 visitors in 2018, while visitation at the wildlife area was estimated to be 5,978 hunting and wildlife viewing visits (iSportsman, 2018; USFWS, 2017). Visitation at Glen Elder State Park has increased over the past two decades. At Glen Elder State Park, trends in state park data over the past 16 years (2023-2022, excluding 2019-2021) indicate increasing visitation at approximately 1.5% per year.

¹⁴These fees and revenues, generally paid by visitors to federal and state governments, are included in the estimate of economic output.



According to BOR, approximately 75% of the visitors participate in water-based activities (swimming, angling, and boating) while 25% participate in shore-based activities. The wildlife area has many different access points around the lake including public hunting fields and a few small campgrounds.

Figure 43. Waconda Reservoir Recreation Areas

Glen Elder State Park hosts many events throughout the year, including the Youth Fishing Tournament, Youth and Women's Pheasant Hunt, Lakefest, many fishing tournaments, weddings, archery shoots, family reunions, Boy Scout/Girl Scout events, school field trips, and outdoor concerts. This wide range of events is everything from small gatherings to large gatherings. Some of the park hosted events that provide meals, drinks, and prizes to youth (Bletscher, 2020).

5.4.1.2. Sport Fisheries

This section provides a summary of sport fishing at Waconda Reservoir. Additional information is provided in the Reservoir Fisheries Technical Report (see Appendix E). Specific fisheries management activities include tailoring fish harvest regulations to changes in sportfish population trends, stocking fish to enhance population abundance as needed, constructing fish attractors to enhance angler success, and maintaining and improving angling access (Appendix E). The Waconda Reservoir lake level management plan identifies the need to increase the water levels between April and June to support nursey habitat. (see Section 4.1.1).

Waconda Reservoir anglers tend to be opportunistic and based on fish availability and water level fluctuation. The last two creel surveys conducted in 2014 and 2019 indicated that most anglers take advantage of whatever species is most readily available at the time. White bass, channel catfish, and crappie comprise the largest contributions to angler's creel in most years (Appendix E).

According to the last creel survey conducted in 2019 there were approximately 43,568 anglers at Waconda Reservoir (Appendix E). Waconda Reservoir is expected to realize fairly stable water levels as it lies on the on the western edge of the wetter portion of the state that provides adequate rainfall to maintain water levels at the reservoir. Periods of extended drought force the water level to decline two to five feet occasionally, but outside of extreme drought situations, water is abundant. River inflow is steady enough to maintain most water levels. At reduced pool, decreased water quality and reduced habitat availability and diversity limit sportfish population abundance and welfare. When Waconda Reservoir is at low pool elevations, aquatic resource-based recreational opportunities available to the public, become more limited. (Appendix E).

5.4.1.3. Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

Like other reservoirs in the state, Waconda Reservoir saw an increase in water elevation in late May 2019. According to USACE existing conditions modeling, , the reservoir rose 8 feet above the top of the multipurpose pool between early May to early June in 2019. The state park was closed as roads were under water, and campers would not have a safe access route within the campground. Water levels remained high, maintaining closures within the park through Labor Day, causing a decline in visitation and entrance fees and revenues. Approximately 80% of the primitive areas were flooded or closed due to no road access. The flood conditions of 2019 had an impact on visitation; visitation was down 14% compared to 2018 levels (KDWP, 2020).

In 2006, 2007, 2012 and 2013 the area suffered a drought. In 2012, water levels were low due to drought conditions and boat access became limited with decreases in vitiation during these conditions. The conservation pool at Waconda Reservoir was fuller than many of the other reservoirs in the region at 85% full in January of 2013. In 2006, Waconda Reservoir was down 7.7 feet, which was extremely low for the lake (KDWP, 2006).

Waconda Reservoir and Glen Elder State Park have not experienced many issues with sedimentation, besides impacts to fish habitat and other issues after flooding events when flood waters recede. At Waconda Reservoir and Glen Elder State Park sedimentation impacts sport fisheries habitat by making certain areas shallower resulting in less habitat for fish. The Osage boat ramp is the main boating access area where sediment can build up and remain after flood waters recede.

5.4.1.4. Critical Lake Elevations for Recreation

Lake elevations are an important factor for water- and shore-based recreation at Glen Elder State Park/Waconda Reservoir. KDWP fisheries experts identified critical lake elevations for recreation at Glen Elder State Park/Waconda Reservoir. These lake elevations are used in the recreation modeling effort to assess the impacts to visitation and economic benefits under FWOP conditions. Other important water surface elevations for the reservoirs are part of the lake level management plans, which specify lake elevations to support fish and wildlife. Future reservoir sedimentation for Waconda Reservoir and any impacts to recreation are described in Section 5.4.2.

5.4.1. Future Without Project Conditions

This section considers the impact of future conditions on recreation, including sediment, water surface elevations, water quality and fishery conditions. The first few sections describe how sediment and water surface elevations will change under the four FWOP scenarios, and how these changes will impact visitation and economic benefits. The FWOP scenarios that include navigation releases are considered in Section 5.4.1.4. A qualitative evaluation of how changes in water quality and fishery conditions will affect recreation in the future is provided in Sections 5.4.1.5 and 5.4.1.6, respectively.

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Lake Elevatior	ns/ <1,445.6 ft	1,445.6 - 1,453 ft	1,453 - 1,457; multi-purpose pool is 1,455.6 ft	1,457 - 1,461.6 ft	1,461.6-1475.6 ft	>1,475.6 ft
Visitation Impacts	There is no boating or water-based access; other shore visitation is decreased from lack of water access.	25% of boating access is available, all other recreation largely unaffected.	No access issues.	80% of boating access is available; all other uses are largely unaffected.	No boat ramps accessible; 75% of lake shore access closed.	All recreation is closed at the lake.
Quality of Recreatior Effects	Aesthetic values decrease dramatically as exposed shorelines grow. Boating safety is a high concern for all visitors due to increase of unmarked underwater hazards.	Safety becomes an issue for remaining boaters; hazards begin to surface.	No impacts	No impacts	Safety becomes an issue for remaining visitors.	Closed

Table 121. Critical Lake Elevations for Recreation at Glen Elder State Park/Waconda Reservoir¹

¹ The information in this table was developed with input from USACE and KDWP staff familiar with Waconda Lake. Lake elevations are in NGVD 1929.

Table 122. Percent of Reservoir Impacted by Critical Lake Elevation Thresholds

Lake Elevations/	<1,445.6 ft	1,45.6-1,455.6 ft	1,455.6; multi- purpose pool is 1,455.6 ft	1,455.6-1,461.6 ft	1,461.6-1475.6 ft	>1,475.6 ft
Water-based Visitor Impacts	100%	75%	0%	20%	100%	100%
Shore-based Visitor Impacts	60%	10%	0%	0%	75%	100%

¹ The information in this table was developed with input from USACE and KDWP staff familiar with Waconda Lake. Lake elevations in are in NGVD 1929.

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5.4.1.1. Changes in Sediment and Water Surface Elevations

This section considers three precipitation conditions under the FWOP scenarios, including typical precipitation periods, drought periods, and high water or flooding periods. To identify the drought and flood years, average annual elevations were analyzed across the period of record. Two years were chosen to evaluate flood conditions (2055, 2097), with average annual elevations above 1,461 feet NGVD 29, when significant impacts to recreation can occur. The modeled year 2023, corresponding with 2019, was also included; average annual elevations in 2123 were modeled to be 1458 feet NGVD 29 although the water surface elevations were considerably higher in after May. Three drought periods were chosen to evaluate drought conditions, with average annual elevations below 1,453 feet NGVD 29. See Table 121 and Table 122 for a description of impacts to recreation at different lake elevation thresholds. Typical years include all other years.

Flood years include:

- 2055 (1951)
- 2097 (1993)
- 2123 (2019)

Drought years include:

- 2029 2030 (1925 1926)
- 2059 2060 (1955 1956)
- 2110 2111 (2006 2007)

5.4.1.1.1. Sediment Conditions

Sediment conditions at Waconda Reservoir/Glen Elder State Park have not recently had impacts to recreation at Waconda Reservoirs, although sedimentation can reduce the amount of fish habitat, notably after flood events. The Osage boat ramp is the main boating access area where sediment can build up and remain after flood waters recede.

Figure 44, Figure 45, Figure 46, and Figure 47, shows the depths of Waconda Reservoir at multipurpose pool under FWOP conditions in 2024, 2049 (25 years), 2074 (50 years), and 2124 (100 years). During typical precipitation conditions (at multi-purpose pool), the Corps sediment modeling indicates that the boat ramps at Glen Elder State Park (marina and Osage Campground) would provide boating access in the future and would not be largely impacted by sediment. The sediment modeling indicates that the largest impacts from deposition would occur in the northwestern portion of the reservoir (Glen Elder State Park is located in the northeastern portion of the reservoir).

During drought conditions, the effects of sediment deposition on recreational access could become more severe as decreasing water surface elevations reduce the depths of the lake (see description on water surface elevations). In addition, boating safety concerns and obstacles are more pronounced with a shallower lake. During flooding conditions, sediment deposition affects the operations of the reservoir and in general can increase water surface elevations as sediment fills the pool over time.



Figure 44. Waconda Reservoir Baseline Depths - 2024



Figure 45. Waconda Reservoir Future Depths with Projected Sedimentation – 2049 (25 Years)



Figure 46. Waconda Reservoir Future Depths with Projected Sedimentation – 2074 (50 Years)



Figure 47. Waconda Reservoir Future Depths with Projected Sedimentations – 2124 (100 Years)

5.4.1.1.2. Water Surface Elevations

Water surface elevations at Glen Elder State Park/Waconda Reservoir are generally higher in the future with increasing sediment deposition in the lake. Table 123 summarizes the average lake elevations over the 100-year period of analysis under the four FWOP scenarios. On average, the lake is slightly less than a foot higher in 2049 and 2074 compared to 2024 conditions. In 2124, Waconda Reservoir is just under one foot higher than under the FWOP 2024 scenarios without navigation releases. Additional information is provided in Appendix B, the Water Management Appendix.

FWOP Scenario	Average Water Surface Elevations	Change in Average Water Surface Elevations from 2024 (ft)
2024	1455.16	-
2049	1455.24	0.08
2074	1455.31	0.15
2124	1455.46	0.30

Table 123. Average Water Surface Elevations at Glen Elder State Park/Waconda Reservoir

Note: The top of the multi-purpose pool is 1,455.6 feet NGVD 29 Represents average across the period of record.

Under both flooding and drought conditions, on average, pools levels are higher in FWOP 2049, 2074, and 2124 conditions than experienced under FWOP 2024 conditions (Table 124). During drought conditions, on average in 2029, 2030, 2059, 2060, 2110, and 2111, pool levels in 25 years (2049) are approximately 0.4 feet higher, while in 50 and 100 years, pool levels are between 0.7 feet to 1.3 feet higher than under 2024 FWOP conditions.

FWOP ScenarioChange in Average Water SurfaceFWOP ScenarioElevations from 2024 DuringDrought YearsDrought Years		Change in Average Water Surface Elevations from 2024 During Flood Years
2049	+0.36	+0.03
2074	+0.70	+0.16
2124	+1.29	+0.13

Table 124. Average Annual Water Surface Elevations During Drought and Flood Years

Note: The top of the multi-purpose pool is 1,455.6 feet NGVD 29

During the 2060-2061 drought period, similar to those experienced in the mid-1950s, under the FWOP 2024 scenarios, the pool is between 1,453 and 1,448 feet NGVD 29 (from two to six feet lower than the top of multipurpose pool) between January 2060 and until June 2061 when it rises back to multi-purpose pool level. Future sediment deposition in 2049 and 2074 increases pool elevations up to one foot higher compared to FWOP 2024 scenarios, while sediment conditions in 2124 FWOP scenarios increase pool elevations by up to two feet during this drought period.

During the 2110-2111 drought period, similar to those experienced in the 2006-2007, under the FWOP 2024 scenarios, the pool is between 1,452 and 1,450 feet NGVD 29 (from four to eight feet lower than the top of multi-purpose pool). Future sediment deposition in 2049 and 2074 increases pool elevations up to two feet higher compared to FWOP 2024 scenarios, while sediment conditions in 2124 FWOP scenarios increase pool elevations by up to four feet during this drought period.

Under three notable high water or flood periods over the 100-year period of analysis, as shown in Table 124 on average, water surface elevations are less than 0.2 feet higher under the FWOP 2049, 2074, and 2124 conditions compared to FWOP 2024, although on any given point over the flood years, the difference between FWOP 2124 water surface elevations and FWOP 2024 water surface elevations can be

up to two feet higher. At peak water surface elevations in the modeled years of 2055 and 2123, there are higher water surface elevations under future scenarios; the modeled year of 2097 shows minimal differences water surface elevations at peak pool levels.

The worst flood year in terms of visitation was in 2055 (modeled after 1951 conditions) when, during the year, water surface elevations were above elevation 1,475 feet NGVD 29 (see threshold table in existing conditions section) for 99 days under 2024 and 2049 FWOP scenarios; there is only a few days of difference when compared to 2074 and 2124 scenarios. In general, Glen Elder State Park/Waconda Reservoir is closed to most visitation when water surface elevations are 1,475 feet NGVD 29.

5.4.1.2. Changes in Visitation

This section describes how changes and lake elevations and sediment conditions can potentially impact visitation. Relatively lower and higher water surface elevations have direct impacts on water-based visitors (boaters, swimmers, anglers) and indirect impacts to shore-based visitors for the recreation areas adjacent to the lake (termed lake-elevation affected recreation areas). In the following sections, we describe the potential impacts to visitation compared to all visitation during typical conditions at the lake-elevation affected recreation areas under the baseline year, 2018. In 2018, 209,300 people visited recreation areas that are potentially impacted by lake elevations, including Glen Elder State Park. The study team also compared the impacted visitation to 2018 baseline visitation at all locations at Waconda Reservoir, including the wildlife area. In 2018, visitation across Glen Elder State Park/Waconda Reservoir, including the wildlife area, was estimated to be 215,200.

In most cases across the Kansas River Basin, visitation across the lakes has been fairly stable over the past 20 years. However, Glen Elder State Park has been experiencing increasing visitation, which has implications to future visitation, consumer surplus, and regional economic impacts.

5.4.1.2.1. Typical Precipitation Conditions

Although sediment affects water surface elevations, the sediment modeling indicates that it is not notably affecting the two boat ramps at Cheyenne and Osage Sediment under the FWOP scenarios (Figures 46, 47, and 48). However, increased sediment accumulation along with flood conditions could impact accessibility of these boat ramps more frequently and severely in the future during flooding conditions. With stable lake elevations anticipated in the future, Glen Elder State Park and Waconda Reservoir are anticipated to continue to draw people to the lake, approximately 215,200 visitors per year (2018 levels).

At Glen Elder State Park, trends in state park data over the past 16 years (2023-2022, excluding 2019-2021) indicate increasing visitation at approximately 1.5 percent per year. If past trends continue in the future, in 75 years, visitation would be close to twice as much as under baseline conditions, although many factors that are difficult to predict can affect future visitation (for example, price of gas, reservoir conditions, economic cycles, availability of alternative recreation areas, etc.). Only reservoir water surface elevations are included in the modeling of visitation.

Slightly higher water surface elevations under the FWOP 2049, 2074, and 2,124 scenarios contribute to slightly higher visitation under these scenarios. Compared to FWOP 2024 modeled visitation during "typical conditions" of 195,500 (excludes the wildlife area), visitation would increase by 1,200, 1,800, and 2,700 visitors per year on average under typical precipitation conditions under FWOP 2049, 2074, and 2,124 scenarios, respectively.

5.4.1.2.2. Drought Conditions

During drought conditions, water surface elevations are considerably lower than the top of multipurpose pool across all FWOP scenarios (up to eight feet lower than multi-purpose pool during the 2110-2111 drought period) and considerably below thresholds important for recreation (1453 feet) for part of this period. In drought conditions, consistent with mid-2000s water conditions, most water-based access at recreation areas at the lake would be impacted under all FWOP scenarios. Multiple years with low water levels can impact the fishery, with additional impacts to anglers and fishing success.

Modeling of water surface elevations and critical lake elevations for recreation in the FWOP 2024 scenario show that in 2110-2111, modeled after mid-2000s drought conditions, visitation at Glen Elder State Park would be 105,400, a reduction of approximately 103,900 visitors from 2018 baseline conditions at Glen Elder State Park (Table 125). The drought period 2029 to 2030 (modeled after 1920s conditions) would have similar impacts to visitation, while conditions in 2059 to 2060 (modeled after the mid-1050s conditions) would have fewer impacts to visitation compared to the other two drought periods.

Drought Periods	FWOP 2024 Modeled Visitation at Glen Elder State Park (Annual)	FWOP 2024 Reduction in Visitation at Glen Elder state Park from Baseline Visitation	Percent Decrease in Visitation at Glen Elder State Park	Percent Decrease from Baseline Visitation (2018) at All Locations
Visitation under Baseline Conditions (2018)	209,300	-	-	215,200
2029-2030	109,800	-99,500	-48%	-46%
2059-2060	130,400	-78,900	-38%	-37%
2110-2111	105,400	-103,900	-50%	-48%

Table 125 Annual Changes in V	lisitation Associated with	Modeled Flood Events	
Table 125. Allitual Changes III	VISILATION ASSOCIATED WITH	wouldered Flood Evenits,	FWUF 2024

Under the FWOP 2049, 2074, and 2124 scenarios, slightly higher water surface elevations would increase accessibility at Waconda Reservoir, with higher visitation compared to FWOP 2024 visitation, an estimated increase of 2,700, 9,200, and 23,600 visits per year during these drought conditions, respectively.

5.4.1.2.3. Flood Conditions

Within the 100-year period of analysis, considerable flood events would occur under the FWOP in 2055 (modeled after 1951 conditions), 2097 (1993), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation in FWOP 2024 conditions show considerable impacts to visitation at Glen Elder State Park (Table 126). A reduction in visitation at Waconda Reservoir would be most sever in in 2055, consistent with conditions experienced in 1951, indicates a potential visitation decrease of 57 percent compared to baseline conditions at Waconda Reservoir (2018).

Flooding Years	FWOP 2024 Modeled Visitation at Glen Elder State Park (Annual)	FWOP 2024 Reduction in Visitation at Glen Elder state Park from Baseline Visitation	Percent Decrease in Visitation at Glen Elder State Park	Percent Decrease from Baseline Visitation (2018) at All Locations
Visitation under Baseline Conditions (2018)	tation under eline 209,300 ditions (2018)		-	215,200
2055	85,700	-123,600	-59%	-57%
2097	99,000	-110,300	-53%	-51%
2123	138,600	-70,700	-34%	-33%

Table 126. Annual Changes in Visitation Associated with Modeled Flood Events, FWOP 2024

Under the FWOP 2049, 2074, and 2122 scenarios, water surface elevations during the three flood events are up to four feet higher compared to FWOP 2024, leading to more closures and reduced visitation. Compared to FWOP 2024 scenarios, visitation during these flood events would on average be 1, 3, and 5% lower under FWOP 2049, 2074, and 2124 scenarios, respectively. The most pronounced impacts would occur in the 2055 event, leading to an additional annual reduction in visitation of 1,000, 1,200, and 1,600 visitors compared to FWOP 2024 visitation under FWOP 2049, 2074, and 2124 scenarios.

5.4.1.3. Changes in Economic Benefits

As described previously, trends in state park data over the past 16 years (2003-2022, excluding 2019-2021), indicate increasing visitation at approximately 1.5 percent per year. If past trends continue in the future, in 75 years, visitation would be close to twice as much as under 2018 baseline conditions. These future increases in visitation will have implications to consumer surplus and regional economic benefits if these factors influencing visitation are not being captured in the modeling effort, with the potential for more than twice the 2018 consumer surplus value under the FWOP 2124 scenario as estimated. However, many factors that are difficult to predict can affect these values (for example, price of gas, reservoir conditions, economic cycles, availability of alternative recreation areas, etc.).

5.4.1.3.1. Consumer Surplus

Consumer surplus values are measured through the Corps' Unit Day Value (UDV) approach further described in Section 2.0. This section describes how changes in lake elevations and sediment conditions can potentially impact recreation consumer surplus values. Sediment deposition and relatively lower and higher water surface elevations have direct impacts on water-based visitors (boaters, swimmers, anglers) and indirect impacts to shore-based visitors at Glen Elder State Park. In the following sections, we describe the potential impacts to consumer surplus values compared to all recreation values during typical conditions at Glen Elder State Park under the baseline year, 2018. Annual visitation during baseline conditions at Glen Elder State Park support an estimated \$1.6 million in consumer surplus value. We also compare the impacted consumer surplus values to baseline visitation and values (2018) at all locations at Waconda Reservoir, including the wildlife area. In 2018, visitation across Waconda Reservoir supported approximately \$1.7 million in consumer surplus values.¹⁵

¹⁵ Consumer surplus values are estimated with recreation visitor day and the Corps' UDV approach. In the modeling effort, visits were converted to recreation visitor days to apply the UDV using an estimate of average number of days per trip at the Kansas City District lakes to estimate consumer surplus. In this appendix, visitation is presented and described for consistency, and not recreation visitor days.

Typical Precipitation Conditions

Under stable reservoir elevations, visitation consistent with 2018 baseline conditions would continue to support consumer surplus values, of approximately \$1.7 million at Glen Elder State Park and the wildlife area.

Drought Conditions

The impacts to visitation during an extreme drought would impact all water-based visitation at lakeelevation impacted recreation areas under all FWOP scenarios. Drought conditions can also affect shorebased visitors if the lake shore is further away from camping and picnic area, or if shallow pools pose unappealing features or conditions (e.g., odors, swampy areas, mosquitoes, etc.). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled droughts years of 2110 and 2111 (modeled after mid-2000s conditions), reduced visitation would translate to a potential loss in consumer surplus values during drought conditions of approximately \$800,000 annually. These reductions in consumer surplus represent an annual decrease of 50% compared to 2018 baseline conditions at Glen Elder State Park.

Table 127. Annual Visitation and Consumer Surplus Changes Associated with Drought Even	nts,
FWOP 2024 (Consumer surplus is provided in FY22\$)	

Drought Year	FWOP 2024 Modeled Visitation at Glen Elder State Park	FWOP 2024 Reduction in Visitation at Glen Elder State Park from Baseline Visitation	FWOP 2024 Reduction in Consumer Surplus at Glen Elder State Park	Percent Decrease from Baseline Consumer Surplus at Glen Elder State Park	Percent Decrease from Baseline Consumer Surplus (2018) at All Locations
Baseline condition (2018)	209,300	-	\$1.6 million	\$1.6 million	\$1.7 million
2029-2030	109,800	-99,500	-\$770,000	-48%	-45%
2059-2060	130,400	-78,900	-\$607,000	-38%	-36%
2110-2111	105,400	-103,900	-\$803,000	-50%	-47%

Under the FWOP 2049, 2074, and 2124 scenarios, slightly higher water surface elevations would increase accessibility at Waconda Reservoir, with higher consumer surplus, an estimated increase of 2%, 7%, and 21% during these drought conditions compared to FWOP 2024 levels, respectively.

Flood Conditions

Within the 100-year period of analysis, considerable flood events would occur in 2055 (modeled after 1951 conditions), 2097 (1993), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss in consumer surplus values during flood conditions of between \$540,000 and \$945,000 million in consumer surplus values, representing a decrease between 34 and 59 percent of total consumer surplus at Glen Elder State Park under baseline conditions (Table 128).

 Table 128. Annual Visitation and Consumer Surplus Changes Associated with Modeled Flood

 Events, FWOP 2024 (Consumer surplus is provided in FY22\$)

Flood Year	FWOP 2024 Modeled Visitation at Glen Elder State Park	FWOP 2024 Reduction in Visitation at Glen Elder State Park from Baseline Visitation	FWOP 2024 Reduction in Consumer Surplus at Glen Elder State Park	Percent Decrease from Baseline Consumer Surplus at Glen Elder State Park	Percent Decrease from Baseline Consumer Surplus (2018) at All Locations
Baseline condition (2018)	209,300	-	\$1.6 million	\$1.6 million	\$1.7 million
2055	85,700	-123,600	-\$945,000	-59%	-55%
2097	99,000	-110,300	-\$840,000	-53%	-49%
2123	138,600	-70,700	-\$540,000	-34%	-32%

Under the FWOP 2049, 2074, and 2122 scenarios, water surface elevations during the three flood events are up to four feet higher compared to FWOP 2024, leading to more closures, reduced visitation and consumer surplus values. Compared to FWOP 2024 scenarios, consumer surplus values during these flood events would on average be one, three, and five percent lower under FWOP 2049, 2074, and 2124 scenarios, respectively. The most pronounced changes in consumer surplus values compared to FWOP 2024 values would occur in the 2124 event, leading to an additional annual reduction of \$26,000, \$50,000, and \$86,000 in consumer surplus values under FWOP 2049, 2074, and 2124 scenarios, respectively.

5.4.1.3.2. Regional Economic Benefits

Regional economic impacts are estimated through the Corp's RECONS model and further described in Section 2. This section describes how changes and lake elevations and sediment conditions can potentially impact regional economic benefits (jobs and income) to adjacent communities. Visitors spend their money in local communities, providing regional economic benefits in these communities. Sediment deposition and relatively lower and higher water surface elevations have direct impacts on water-based visitors (boaters, swimmers, anglers) and indirect impacts to shore-based visitors for the recreation areas adjacent to the lake (termed lake-elevation affected recreation areas). In the following sections, we describe the potential impacts to regional economic benefits from reduced visitation compared to regional economic benefits supported under baseline conditions in 2018. Consistent with visitation in 2018, 215,300 visitors to Glen Elder State Park and the wildlife area support 78 jobs and \$2.2 million in labor income in the local economy; 209,300 visitors at Glen Elder State Park support 62 jobs and \$1.7 million in labor income.

Typical Precipitation Conditions

Under stable reservoir elevations, visitation consistent with 2018 baseline conditions would be expected to continue to support regional economic benefits in the local economy surrounding Glen Elder State Park and the wildlife area, estimated to be 78 jobs and \$2.2 million in labor income.

Drought conditions

Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled drought years of 2110-2111 (modeled after mid-2000s conditions), reduced visitation would lead to a potential loss of 31 jobs and \$865,000 in labor income during drought conditions under 2024 FWOP compared to baseline conditions at Glen Elder State Park (Table 129).

There would be similar impacts under FWOP 2049, 2074, and 2124 conditions. These reductions in economic benefits impacted by changes in lake elevations represent a 39 percent decrease in jobs from total jobs supported from all visitor spending at Waconda Reservoir under baseline conditions (78 annual jobs). Droughts can also have lasting impacts to tourism business depending on the timing of the recovery and resiliency of the businesses, including the reservoir refilling, the re-establishment of the fishery, steps to mitigate losses in visitation, and the demand for recreation at the lake.

Table 129. Annual Visitation and Changes in Regional Economic Benefits Associated wit
Drought Events, FWOP 2024 (Labor income is provided in FY22\$)

Drought Year	FWOP 2024 Modeled Visitation at Glen Elder State Park	FWOP 2024 Reduction in Visitation at Glen Elder State Park from Baseline Visitation	FWOP 2024 Reduction in Jobs at Glen Elder State Park (annual)	FWOP 2024 Reduction in Labor Income at Glen Elder State Park (annual)	Percent Decrease in Jobs and Income from Baseline Conditions at All Locations
Baseline condition (2018)	209,300	-	62	\$1.7 million	78 jobs/\$2.2 million
2029-2030	109,800	-99,500	-30	-\$859,000	-39%
2059-2060	130,400	-78,900	-31	-\$835,000	-39%
2110-2111	105,400	-103,900	-31	-\$865,000	-39%

Flood Conditions

Within the 100-year period of analysis, considerable flood events would occur in 2055 (modeled after 1951 conditions), 2097 (1993), and 2123 (2019). Modeling of water surface elevations and critical lake elevations for recreation under FWOP 2024 conditions show that in modeled flood years, reduced visitation would translate to a potential annual loss of up to 40 jobs and \$1.1 million in labor income, representing a decrease up to 50 percent of total jobs supported by visitor spending at Waconda Reservoir under baseline conditions (Table 130).

Table 130. Annual Visitation and Changes in Regional Economic Benefits Associated with Floor
Events, FWOP 2024 (Labor income is provided in FY22\$)

Flood Year	FWOP 2024 Modeled Visitation at Glen Elder State Park	FWOP 2024 Reduction in Visitation at Glen Elder State Park from Baseline Visitation	FWOP 2024 Reduction in Jobs at Glen Elder State Park	FWOP 2024 Reduction in Labor Income at Glen Elder State Park	Percent Decrease in Jobs and Income from Baseline Conditions at All Locations
Baseline condition (2018)	209,300	-	62	\$1.7 million	78 jobs/\$2.2 million
2055	85,700	-123,600	-40	-\$1,099,000	-50%
2097	99,000	-110,300	-28	-\$743,000	-34%
2123	138,600	-70,700	-17	-\$461,000	-21%

Damages, Revenues, and Fees to States

Visitation to Glen Elder State Park contributes considerable revenue to the state to maintain parks. Revenue is collected through park entrance fees, camping fees, hunting and fishing license revenues, concessionaire fees. In 2018, the revenues associated with Glen Elder State Park were \$317,992.¹⁶ At Glen Elder State Park in 2019, these revenues were \$297,964, a reduction of six percent from 2018 revenues due to reduced visitation from flooding events.

Hunting and fishing license sales are also important for the state, bringing in \$31.2 million in 2018 across the state, although this data is not available by lake. In general, these revenues vary over time and are typically proportional to visitation at the lakes. As described in this section, sediment deposition, droughts, and flooding conditions can have considerable impacts on this visitation and therefore revenue sources for the state. The evaluation indicates that drought conditions could result in an annual decrease of visitation up to 48 percent of baseline conditions (2018), while flooding impacts would have slightly larger impact, impacting up to 57 percent of visitation under baseline conditions. These impacts would continue to occur overtime when droughts or flooding occur, with their occurrences becoming more frequent with climate change.

During these extreme events, the state and USACE often incur costs to repair damages, conduct small scale dredging, and other actions to repair or maintain infrastructure. Therefore, the state has less revenues coming in, with increased expenses, often impacting state coffers for years.

Estimated costs for repairs of recreational infrastructure (\$1,500) associated with damage from the 2019 flood at Glen Elder State Park include damages to docks, campsites, and parking lots. These damages are likely to continue to occur in the future with extreme events.

5.4.1.4. Navigation Releases

There were no navigation releases at Waconda Reservoir because Waconda Reservoir operations do not support navigation on the Missouri River.

5.4.1.5. Water Quality

All reservoirs in the Kansas River Watershed, including Waconda Reservoir, will likely experience increasing effects of aging. Future water quality within the Kansas River watershed lakes is dependent on multiple influencing factors, some of which are challenging to predict and/or estimate. It can be assumed that continued, and increasing fertilizer use, will continue to influence the water quality of runoff, groundwater, streams, and lakes. Approximately 40% of the total watershed area is classified as Grassland/Herbaceous and Pasture/Hay, much of which is used as rangeland/stock areas for livestock in the watershed. The Kansas Department of Agriculture (2021) publishes total numbers of livestock (cattle, sheep, hogs), and increasing trends in the numbers of animals that require feed and produce increased quantities of manure, indicate the potential for worsening water quality in downstream lakes.

Continued and enhanced water quality impairment may be expected at Waconda Reservoir. Consistent with existing conditions, storm events generating high run-off volumes will continue to transport the majority of sediment and nutrient loads to Waconda Reservoir. Deposited and suspended sediments affect aquatic habitat and life, contributing to reduced abundance and diversity via smothered spawning sites, inhospitable macroinvertebrate habitat, increased turbidity, reduced light availability, inhibited phytoplankton and macrophyte growth, diminished sight and filter-feeding, and water temperature effects.

The nutrients nitrogen and phosphorus are abundantly available throughout the Kansas River Watershed. A watershed-wide pattern of increasing in-lake total phosphorus concentrations suggests potential for continued eutrophication (high algal productivity) at Kansas River Watershed reservoirs. Phosphorus is

¹⁶These fees and revenues, generally paid by visitors to federal and state governments, are included in the estimate of economic output in described in Section 3.4.1.2.3.

often considered a nutrient that limits primary productivity (e.g., phytoplankton, aquatic plants), although nutrient limitation of phytoplankton growth is dependent on species and may vary depending on time and location. Too much phosphorus can cause increased growth of algae and aquatic plants, which can result in decreased levels of dissolved oxygen, a process called eutrophication.

Waconda Lake is associated with high phosphorus from inflows captured by eutrophication sulfates. Waconda Lake has relatively high total phosphorus mean, which is the primary cause of eutrophic conditions leading to increased algal production. Similarly, mean chlorophyll concentrations are also considered eutrophic (KDHE 2003). In addition, total nitrogen mean value at Waconda Lake exceeded the EPA Ecoregional Recommended Criteria (EPA 2001). However, HAB warnings have not been issued by KDHE in recent years.

Although HAB warnings have not been issued for Waconda Reservoir in recent years, deteriorating water quality could eventually lead to increased prevalence of HABs in Waconda Reservoir with adverse impacts to visitors in the future. Due to their ability to possibly release toxins detrimental to human and animal health, along with their ability to destroy aquatic habitat and life, and their unsightliness, HABs have the potential to further decrease recreation in the future at Waconda Reservoir. Extreme or persistent HAB conditions can also deter visitors from coming to the lake.

5.4.1.6. Angling and Sport Fishery

In the future, Waconda Lake is expected to have fairly stable water levels as it lies on the western edge of the wetter portion of the state that currently provides adequate rainfall to maintain the water level. Water levels play a crucial role in fish production and angler participation, affecting state park visitation and the local economy surrounding the reservoir. Generally, Waconda Reservoir possesses adequate water quality to promote sportfish survival during typical precipitation conditions, and turbidity at the lake falls within the ideal range for Kansas reservoirs. These conditions are anticipated to continue in the future, supporting fish habitat and angler visitation.

However, periods of extended drought generally force a decrease in the water surface elevations from 2 to 5 feet. At reduced pool, decreased water quality and reduced habitat availability and diversity limit sportfish population abundance and welfare. When Waconda Reservoir is at low pool elevations, aquatic resource-based recreational opportunities available to the public become more limited. Specific conductivity and total dissolved solids are normally high and become extremely concentrated as the reservoir volume decreases. The stress on the fishery is likely to continue in the future with drought conditions, with adverse impacts to fishing success for anglers, decreased angler visitation, and reduced regional economic benefits to adjacent communities; climate change may cause more severe and frequent drought events, increasing the likelihood of these conditions in the future.

In addition, sediment will continue to accumulate in Waconda Reservoir with an expected additional 13% loss of the multipurpose pool over the next 25 years (2049), 20% loss over the next 50 years (2074), and further sediment deposition expected over 100 years. Many sportfish such as walleye, white bass, black bass and Centrarchid sportfish prefer to deposit eggs on clean, larger-grain substrates to avoid suffocation of eggs by silt. Thus, availability and diversity of rock substrate is important to successful reproduction of these and other fish species. Silt deposited in Waconda Reservoir from sedimentation can reduce the diversity of rock substrate in the reservoir affecting reproduction of fish species that rely on this habitat. Loss of fish habitat is anticipated to continue into the future with increasing sediment deposition, with the potential for reduced fishing success for anglers.

5.5. Webster Reservoir

Webster Reservoir is located eight miles west of Stockton, Kansas between Woodston and Osborne, Kansas on the South Fork of the Solomon River (Figure 48). Webster State Park is an 880-acre prairie setting of rolling hills, and visitors often see deer, turkeys, quail, pheasants, and many wildflowers. The 3,700 acres of open water offer many fishing opportunities in Webster Reservoir. Located in the central flyway, the lake is a stopping place for many species of waterfowl and shorebirds and offers opportunities for outdoor enthusiasts for hunting, wildlife watching, and photography.

Webster Wildlife Area encompasses 8,018 acres mostly surrounding the Solomon River west of Webster Reservoir. At the Wildlife Area, a variety of wildlife habitats are maintained to enhance wildlife. The lake is known for its walleye, crappie, white bass, and channel catfish.



Figure 48. Webster Reservoir Recreation Areas

5.5.1. Existing Conditions

5.5.1.1. Recreation Facilities and Visitation

Webster Reservoir offers 50 miles of shoreline and the following recreational amenities: boating, camping, fishing, hunting, water sports and picnicking. Specifically, the area offers:

- Campgrounds
- Campsites
- Picnic Areas
- Beaches

- Boat Ramps
- Private Cabins (administered by KDWP on USBR property)

The KDWP is also responsible for administering the contract for eight private cabins that are located on USBR property. In 2018, visitation to the area was 102,522 visitors. This visitation estimate does not

include visits to the private cabin areas and the wildlife area. iSportsman hunting data isn't currently available for Webster Reservoir. It is assumed that one percent of total visitation (1,025 visits with full compliance) is hunting within wildlife areas, based on averages from other lakes. Additionally, it is assumed that 20% of that number (205) accounts for wildlife viewing based on a USFWS report that provides state-wide hunting, fishing, and wildlife viewing trips in Kansas³(USFWS, 2017).

Approximately 65% of the visitors to the lake participate in water-based activities (swimming, angling, and boating) while 35% participate in shore-based activities. Webster Reservoir hosts numerous events throughout the year. These events include a fireworks displays and activities for children. Some smaller events are the Webster Car Show and Stockton Cross Country race. Webster State Park also hosts campout events for Boy Scouts, Girl Scouts and 4-H clubs, and family reunions, weddings, school field trips and several fishing tournaments.

5.5.1.1. Sports Fisheries

This section provides a summary of sport fishing at Webster Reservoir. Additional information is provided in the Reservoir Fisheries Technical Report (see Appendix E). The general objective of fisheries management at Webster Reservoir is to optimize the quality and diversity of angling opportunities. Specific management activities include tailoring fish harvest regulations to changes in sportfish population trends), stocking fish to enhance population abundance as needed, construction of fish attractors to enhance angling opportunities, and other activities for maintaining/improving angling access (Appendix E).

Reservoir sportfish species accounts and factors affecting their abundance and distribution are included below. It is notable that inherent variability exists in statistics generated from fish population sampling efforts. Changes in reservoir water level, abundance and distribution of flooded terrestrial vegetation, turbidity or lack thereof, etc. can alter fish behavior and feasibility of deploying sampling gear, thus potentially increasing variability of sampling results. As a result, sampling results must be viewed with a degree of skepticism, require interpretation by workers utilizing the data, and often require a series of greater than one year for representative trends to become apparent (Appendix E).

According to the last creel survey, the number of angler trips in 2017 was estimated to be 12,937 (Appendix E). Walleye are the first most sought after species, according to the last creel survey conducted in 2017. The species is highly sought after and grow rather quickly. Black and white crappie are the second most sought after species. The crappie population is rather cyclical, due to the fact that Webster Reservoir is an irrigation reservoir. When the water level is around conservation pool (1,892.45 above msl) they do rather well, however, when the elevation gets below 1,884 msl they suffer. Crappie habitat

improved considerably over the last four years as the reservoir elevations rose and remained around conservation pool or slightly above conservation pool during crappie spawns. Channel catfish and flathead catfish both occur in Webster Reservoir and are usually in the top four species that anglers target. Channel catfish numbers typically stay relatively consistent. However, the population typically does better at the higher water elevations than they do at the lower elevations. Flathead catfish are also sampled and usually occur in lower numbers than channel catfish. White bass are the fourth most sought after species. White bass numbers are typically relatively stable, and anglers are pretty good at catching them. There is no creel limit and they grow rather quickly, thus, enticing anglers of all ages and gender.

If irrigation withdrawals continue the reservoir will continue to see wide fluctuations in the amount of water it contains. At reduced pool elevations, decreased water quality and reduced habitat availability and diversity limit sportfish population abundance and welfare. When Webster Reservoir is at low pool elevations, aquatic resource – based recreational opportunities available to the public, become more limited. This trend is expected to continue in the future with impacts to the reservoir and to reservoir fisheries occurring when the reservoir is at low pool elevations either from lack of inflows, lowering of conservation pool during irrigation releases, and a combination of the two. While sedimentation will continue to occur (3.3% loss of the MP over the next 50 years) it is not expected to create impacts to reservoir fisheries or their habitat in the future. If the invasive species Phragmites increases at Webster Reservoir there could be issues related to reservoir fisheries unable to access habitat (e.g., shorelines, coves) in the future. Fish species that inhabit Webster Reservoir are not expected to change in the future but will have periods where changes in abundance and shifts in sportfish species dominance occur from conditions that affect habitat quantity and quality, similar to what is now experienced at Webster Reservoir.

5.5.1.2. Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

During the 2018 and 2019, Webster Reservoir recreational facilities were affected by flooding. Both years, the water level reached approximately seven feet above multipurpose pool. Once water levels reach 2.1 feet above multipurpose pool, the Rock Point utility campground and Lakeview primitive campground and road are affected; the main park road must close at 5.5 feet above multipurpose pool. In 2018, Rock Point campground and Lakeview primitive campground/road was closed for 1.5 months, and the main park road was closed for 13 days. In 2019, Rock Point Campground and Lakeview primitive campground/road was closed for 4.5 months total on two different occasions, and the main road was closed for 1.5 months. Four areas required rip rap for shoreline stabilization: Old Marina, the road east of the archery range, Lakeview and Goose Flats (Webster Annual Report 2020). Despite this, visitation increased by 30% overall compared to 2018. This was driven by a very large increase in the fall (SepDec) of 127% (KDWP 2018-2019).

Webster State Park is not heavily impacted by sediment, as an irrigation lake, it gets drawn down regularly. Occasionally, sediment will accumulate when the water levels are low, but there is little impact to recreation.

It is not unusual for the reservoir to be 15 to 20 feet below multipurpose pool and it has been down around 30 feet a couple different times (1972 and 1992) since construction. Once the reservoir gets this low it usually takes a significant rain event or series of events to get it back up to conservation pool. The area experienced a drought in 2012 and into 2013. In 2012, even though the reservoir water levels were relatively low, visitation and annual fees and revenues were some of the highest recorded at Webster State Park. Historically, water levels are positively correlated with visitation; water levels increase, and visitation also increases. In 2012, the reservoir during peak season ranged from three feet to 12 feet below

multipurpose pool, which is a common level, and all facilities and boat access points were usable. The multipurpose pool was 47.7% full in January of 2013.

More recently, HABs have also had a potential impact on visitation. During a "HAB watch," park users are advised that HABs have been seen and may still be present and to use caution when getting in the water. Typically, after watches have been announced, day use slows although camping reservations are not typically affected. When a HAB "warning" is announced, the swimming beach is closed and contact with water must be avoided. HAB warning levels significantly decrease day use and camping reservations. In 2018, Webster had three closures in June and August, the only lake in the Kansas River Basin to experience closures from HAB hazards in 2018. There were HAB warnings in July, September and October, and visitation fell by 21%, 50% and 43% respectively compared to monthly averages. There were HAB closures in June and August, and visitation dropped 7% and 39% respectively compared to monthly averages. Overall visitation dropped by 15% compared to 2017. In 2020 a HAB watch was issued in July and remained in effect until early September. The watch was lifted, only to be reinstated in mid-September and lifted in late September (Webster Annual Report 2020).

5.5.1.1. Critical Lake Elevations for Recreation

Lake elevations are an important factor for water- and shore-based recreation at Webster Reservoir. KDWP fisheries experts, critical lake elevations for recreation were identified at Webster Reservoir as well as the corresponding impacts to visitation. These lake elevations are used in the recreation modeling effort to assess the impacts to visitation and economic benefits under FWOP conditions. Other important water surface elevations for the reservoirs are part of the lake level management plans, which specify lake elevations to support fish and wildlife.

5.5.1. Future Without Project Conditions

This section considers the impact of future conditions on recreation, including sediment, water surface elevations, water quality and fishery conditions. Qualitative methods only were used to assess the effects of harmful algal blooms, water quality issues, habitat availability, and changes to reservoir fisheries on recreation at reservoirs that were not modeled and assessed quantitatively. The information used to qualitatively assess recreation was based on research, documents (e.g., Kansas State Wildlife Action Plan), information from subject matter experts, and data generated prior to the study or during the study (e.g., projected sedimentation in reservoirs; assessments of reservoir fisheries).

Because USACE sediment modeling indicated very few impacts to future sediment conditions and because no H&H modeling was conducted for Webster Reservoir, FWOP recreation impacts from sediment and changes in water surface elevations were evaluated qualitatively for this reservoir.

5.5.1.1. Recreation Facilities and Visitation

KDWP will continue to operate and maintain the existing recreation facilities at Webster Reservoir. Visitation during average water years will be similar to the visitation under baseline conditions (102,522 visitors annually). Special events will continue to be hosted at the reservoir similar to past special events.

Webster Reservoir is expected to continue a similar water level fluctuation pattern as irrigation to meet farmland requirements both above and below the reservoir will remain of upmost importance. When Webster Reservoir is at low pool elevations, aquatic resource-based recreational opportunities available to the public become more limited.

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Lake Elevations/	<1,860 ft	1,860-1,869 ft	1,869-1,879.6; multi-purpose pool is 1,892.45 ft	1,879.6-1,894.4 ft	1,894.4-1,896.3 ft	>1,923.7 ft
Visitation Impacts	There is no boating or water-based access; other shore-based visitation is decreased from lack of water access.	25% of boating access is available with limited water recreation, all other recreation largely unaffected.	No access issues	Low access issues	Main road is closed below the bait shop,boat ramps access is limited; 75% of lake shore access is closed.	All recreation is closed at the lake.
Quality of Recreation Effects	Aesthetic values decrease dramatically as exposed shorelines grow. Boating safety is a high concern for all visitors due to increase of unmarked underwater hazards.	Safety becomes an issue for remaining boaters; hazards begin to surface.	No impacts	Boating access becomes affected at the upper end of this elevation range	25% of primitive camping affected in the State Park at the bottom end of this elevation. Safety becomes an issue.	Closed

¹ The information in this table was developed with input from USACE and KDWP staff familiar with Webster Lake. Lake elevations are in NGVD 1929.

Table 132. Percent of Reservoir Impacted by Critical Lake Elevation Thresholds

Lake Elevations/	<1,860 ft	1,860-1,869 ft	1,869-1,879.6; multi-purpose pool is 1,892.45 ft	1,879.6-1,894.4 ft	1,894.4-1,896.3 ft	>1,923.7 ft
Water-based Visitor Impacts	100%	75%	0%	20%	100%	100%
Shore-based Visitor Impacts	50%	0%	0%	0%	75%	100%

¹ The information in this table was developed with input from USACE and KDWP staff familiar with Webster Lake. Lake elevations are in NGVD 1929.

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5.5.1.2. Sport Fisheries

At reduced pool elevations, decreased water quality and reduced habitat availability and diversity limit sportfish population abundance and welfare. When Webster Reservoir is at low pool elevations, aquatic resource – based recreational opportunities available to the public, become more limited. This trend is expected to continue in the future with impacts to the reservoir and to reservoir fisheries occurring when the reservoir is at low pool elevations either from lack of inflows, lowering of conservation pool during irrigation releases, and a combination of the two.

Fisheries management objectives will continue to optimize the quality and diversity of angling opportunities through enhancement of population abundance as needed. Fisheries management measures will continue to include fish harvest regulations, fish attractors, stocking as needed, and sampling to monitor trends. Creel surveys for angler use and preferences will also continue to support management of the fisheries. Fish species that inhabit Webster Reservoir are not expected to change in the future but will have periods where changes in abundance and shifts in sportfish species dominance occur from conditions that affect habitat quantity and quality, similar to what is now experienced at Webster Reservoir.

5.5.1.3. Effects of Sediment, Flooding, and Drought Conditions on Recreation

The effects of sediment on recreation at Webster Reservoir will be similar to past conditions with only minor localized effects by sediment issues. Sediment will continue to accumulate in Webster Reservoir with an expected additional 2.2 % loss of the multipurpose pool over the next 25 years (2049) and 3.3% loss over the next 50 years (2074) (Appendix D).

Similar to past droughts water levels will decrease due to increased irrigation usage causing visitation to slowly decrease during drought periods and fishing and boating could decrease. Impacts to recreation can occur when reservoir elevations are more than 23 feet below top of multipurpose pool with reduced boating access and limited water recreation. Safety also becomes an issue during these conditions from underwater hazards. With climate change these decreases in visitation could be more frequent and prolonged leading to longer effects to recreation in the future.

Webster Reservoir typically can experience long periods of drought that can occur over multiple years when the water elevations are substantially below the top of multipurpose pool and often when high inflows occur it does not cause water elevations into the flood pool. Similar to other reservoirs in this part of the basin visitors will come to the reservoir when other reservoirs have limited access. However, Webster Reservoir has experienced impacts during past flooding events with higher pool elevations that caused impacts to recreation and damages to recreation infrastructure. These impacts are expected to continue in the future at Webster Reservoir during high flood pool conditions. Impacts from reduced access for boating and shore-based recreation start at approximately two feet above top of multipurpose pool and above 1923.7 feet all recreation is closed at the reservoir. In 2018, the revenues associated with Webster Reservoir were \$217,027.¹⁷ At Webster Reservoir in 2019, these revenues were \$267,647, an increase of 19% from 2018 revenues due to increased visitation from higher multipurpose pool elevations and flooding events in the region.

During periods when the reservoir reaches the critical lake elevations for recreation the impacts (high and low), described in Table 131 and Table 132, to water-based and shore-based visitors are likely to occur with impacts to recreation leading to economic effects in the state and the region. With expected climate

¹⁷These fees and revenues, generally paid by visitors to federal and state governments, are included in the estimate of economic output.

prediction of more frequent extreme flood events this may lead to more frequent impacts to recreation and damages to recreation infrastructure.

Water quality at Webster Reservoir and expected future conditions related to water quality are included in Appendix G. Impairments associated with high phosphorus and sediment load and naturally occurring sulfate and selenium in the watershed will continue and potentially will decrease with the established TMDL. HAB will continue in the future from cyanobacteria blooms causing potential warnings during the recreation season. Climate is a fundamental driver of nutrient and sediment transport and expected future climate conditions will directly impact transport from land surface to streams and reservoirs.

6.0. Harlan County Reservoir

The Harlan County Reservoir includes a dam and a reservoir of 13,250 acres and 75 miles of shoreline located in Harlan County in south-central Nebraska (Figure 49). Its southernmost part extends into northern Phillips County, Kansas. Harlan County Lake is located seven miles from the Nebraska/Kansas state line and 60 miles south of Kearney, Nebraska, a town of approximately 30,000 residents. Harlan County Reservoir is Nebraska's second largest lake.

Harlan County Reservoir has two marinas that are adjacent to full-time trailer courts. This creates a smalltown experience on USACE lands. Both areas have over 100 trailers, over 100 campsites, restaurants, as well as the marina. Patterson Harbor also has cabins that can be leased. USACE manages and maintains all parks/recreation areas except for the marina which is privately run (Lake meeting 9/27/21).

There are several housing developments that are adjacent to USACE property at Harlan County Reservoir hosting second homes for many in the region. One community, Republican City, Nebraska, has over 50% of the residences owned by people from the area (Harlan County, 2020).

6.1. Existing Conditions

6.1.1.1. Recreation Facilities and Visitation

Harlan County Reservoir offers a variety of recreational amenities, including:

- Boat Ramps
- Visitor Center
- Swimming Areas
- Marinas
- Playgrounds
- ATV Trails

- Picnic Areas/Shelters
- Campsites
- Fish Cleaning Stations
- Trails (walking, biking, horseback)
- Alma City Park

Visitation in 2018 was 921,938 visitors (USACE VERS). The area's most popular recreation areas in 2018 were North Shore Marina and Patterson Marina representing 28% and 24% of total visitation, respectively (USACE VERS). In terms of activities, camping and water-contact activities were the most popular representing 25% and 20% of all activities, respectively. Angling and boating accounted for 7% and 12% of total activities at the reservoir in 2018. Hiking, jogging, sightseeing and picnicking accounted for 28% of activities at the reservoir (2018 USACE VERS). Float trips using tubes and canoes is a popular sport below the dam at Harlan County Reservoir, attracting about 1,000 people a day during the summer. The study team has assumed that one percent of total visitation (8,181 visits with full compliance) is hunting within wildlife areas, based on averages from other lakes. Additionally, it is assumed that 20% of that figure (1,636) accounts for wildlife viewing based on a USFWS report that provides state-wide hunting, fishing, and wildlife viewing trips in Nebraska³ (USFWS, 2017).



Figure 49. Harlan County Reservoir Recreation Areas

There are three large fishing tournaments in May and June that draw many visitors on a consistent basis. The City of Alma, Nebraska puts on a 4th of July road race, parade, and firework show at Harlan County Reservoir. These special events accounted for 2% of activities in 2018.

6.1.1.2. Sport Fisheries

This section provides a summary of sport fishing at Harlan County Reservoir. Additional information is provided in the Reservoir Fisheries Technical Report (see Appendix E). Current fisheries management activities include fish stocking, fishery surveys, fishing regulations, angler access improvements, aquatic habitat restoration, and outdoor education. Priority management species for the Harlan County Reservoir sport fishery, determined by population histories and angler preferences, are walleye, white bass, and channel catfish. Wipers are managed as a species with trophy potential with a low-density population goal. Crappie, largemouth bass, and northern pike are typically included in sport fishery management details when the reservoir is at higher elevations (1,940 msl and above).

Based on creel surveys at Harlan County Reservoir walleye, white bass, channel catfish make up the majority of fishing trips, comprising 84% of the total trips on average. The average annual percentages for angler trips seeking walleye, white bass, and channel catfish were 31%, 39%, and 14%, respectively. Average annual trips for anglers seeking walleye, white bass, and channel catfish were 8,533, 11,768, and 3,556, respectively. For walleye, the long-term averages for annual catch and harvest were 12,748 and 2,834, respectively. Walleye catch and harvest were low from 2008 to 2010, but generally increased since 2010 (Appendix E).

With wide fluctuating water levels associated with drought periods and contrasting high inflows, reservoir waters levels have varied greatly over time. Some fish species temporarily benefit from water level patterns experienced at Harlan County Reservoir. When years of drought and low reservoir water levels are followed by high inflows and high reservoir water levels, shoreline-oriented species such as largemouth bass and crappie benefit from an abundance of flooded shoreline terrestrial vegetation. Many coves at Harlan County Reservoir have experienced major shoreline erosion where they connect to the reservoir and are now separated from the main reservoir during lower water level periods. Coves with major erosion problems include Bone, Indian, Methodist, Prairie Dog, and Tipover Coves. USACE dredging operations are used to maintain connection to the main reservoir at Gremlin and Patterson Coves and provide access for all boating activities. The USACE has placed rock on shorelines at Gremlin, Methodist, and Patterson Coves to protect public access and campground resources.

Large water level fluctuations are likely to continue as this reservoir serves multiple purposes including reducing flood risk and providing irrigation. These circumstances create challenges at low water levels including reduced connectivity with cove habitat, which reduces spawning and rearing habitat for shoreline orientated species such as crappie, largemouth bass, and bluegill. Low water levels can also increase the chances of harmful algae blooms and fish kills while decreasing user access and recreational opportunities. Extremely high-water levels (above conservation pool) can present challenges as well including excessive shoreline erosion and damage to infrastructure such as breakwaters, fishing piers, and boating access developments. Harlan County Reservoir is also used as the storage reservoir for water dedicated to the Republican River compact between Colorado, Nebraska and Kansas, which tends to lead to increased water releases during the time of the year when small fish are vulnerable to entrainment.

Addressing erosion and disconnection of cove habitat has been a priority at Harlan County Reservoir. For example, a large aquatic habitat project was completed in 2012-2013 at Gremlin and Patterson Coves, which included bank stabilization, protection breakwaters, dredging, and angler access improvements. This project was planned and funded by NGPC through the Aquatic Habitat Program. A second aquatic habitat project was initiated in 2022 and is currently in the planning phases with USACE Continuing Authorities Program Section 1135 Ecosystem Restoration funding. This goal of this project is to improve habitat and connectivity at Methodist Cove, which is located on the northwest edge of the reservoir.

The introduction of invasive species is also a concern at Harlan County Reservoir. Although zebra and quagga mussels have yet to be detected in Harlan County Reservoir, these invasives are common in nearby Kansas reservoirs posing a potential future threat to the aquatic resources, infrastructure, and recreational opportunities in this reservoir. Continued monitoring and outreach/education efforts will be important for minimizing the potential for future introductions.

6.1.1.3. Recent Effects of Sediment, Flooding, and Drought Conditions on Recreation

Harlan County Reservoir is a fairly flat-bottomed lake, so even small elevation changes result in large drops in surface areas. On average, the lake drops four to eight feet per year from what is considered normal pool elevation. However, during droughts the pool can decrease from 10 to 12 feet over multiple years. These low elevations can result in visitation to the lake dropping by up to 50%. The shorelines surrounding the lake are essentially all composed of loess material, and continued erosion and sedimentation have closed off most of the natural coves.

Drought conditions can impact recreation and irrigation activities at Harlan County Reservoir and downstream, as seen during the drought of 2012. When Harlan County Lake water levels are low, fish species are unable to reach the coves which provide critical spawning and rearing habitat. Low water conditions are typical as the lake is within a region with low average annual rainfall and during periods of

use for irrigation water supply. Low water conditions are negatively affecting the abundance of fish species (USACE 2020). Boater access and shifts in usage patterns are a challenge during drought years, like 2012. The boat ramps in Hunter Cove, Methodist Cove and the City of Alma become unusable during these low water conditions. To mitigate the lack of access, low water ramps have been built in both Cedar Point and Hunter Cove. Dredging has allowed for boating access at both Gremlin and Patterson coves down to the minimum pool level. Harlan County Reservoir has a congressionally authorized cutter head dredge that is used to remove sediment in these areas. Dredging can only be completed during very specific lake levels, limiting the ability to mitigate these adverse effects. Harlan County Lake is legally bound to a minimum elevation of 1,927 feet.

Due to the spring flood event in 2019, the lake was above multipurpose pool for over 100 days, with a max crest of 10 feet above top of multi-purpose pool (USACE 2020). Due to high water and erosion a tremendous amount of silt washed into boat ramp areas and channels. Areas affected include Patterson, Methodist, Hunter, and Gremlin coves. Irrigation releases impact the viability of tubing below the dam, which are controlled by the USBR. Water levels at or above 600-700 cfs can be dangerous, as can levels below 200-250 cfs. The campground at Methodist Cove, was closed from July 6th for the remainder of the season in 2019. Additional closures occurred in Hunter Cove, Gremlin Cove, and Cedar Point. In addition, the North Shore Marina was closed in the beginning of July as well. This marina has a considerable impact on overall visitation as there are 135 full time trailer homes, 150 campsites, a large restaurant and marina store. Overall, the 2019 flood contributed to a 15% decline in visitation compared to 2018. This was driven by 25% decrease in the winter (Jan-Apr) and a 16% decrease in the summer (May-Aug) (USACE and KDWP 2018-2019).

Shortly following dam closure in 1951 wave action in the new lake environment began eroding loess soils along the new shoreline and depositing sediment into the lake. Wind, waves, and water current patterns transport eroded sediments throughout the lake resulting in the sedimentation of several cove entrances, making access to these coves during low water periods difficult to impossible for both fish and boats (USACE 2020). Sedimentation in coves and marinas has also impacted fish habitat and visitation. Drought conditions can shift silt around and fill in coves in the lake. At about six feet below the multipurpose pool most coves lose recreational access. Sediment impacts water based visitation the most, especially angling opportunities due to loss in spawning habitat. Sediment deposition occurs primarily from shoreline erosion of areas surrounding the reservoir. Congress approved a dredge for Harlan County in the 1970's just to keep marinas, coves and boat ramps open, and it has been used on average every two to three years. All cove access is now completely blocked in areas that have not been dredged (Janicek, 2020).

6.1.1.4. Critical Lake Elevations for Recreation

Lake elevations are an important factor for water- and shore-based recreation at Harlan County Reservoir. Working with the USACE lake staff and NGPC fisheries experts, critical lake elevations for recreation were identified at Harlan County Reservoir as well as the corresponding impacts to visitation. Other important water surface elevations for the reservoirs are part of the lake level management plans, which specify lake elevations to support fish and wildlife. Page left intentionally blank.

Table 133. C	ritical Lake E	levations for R	ecreation at Harlan	County	Reservoir ¹

Lake Elevations	<1,933 ft	1,933-1,942 ft	1,942-1,948; multi-purpose pool is 1,945.7 ft	1,948-1,952 ft	1,952-1,955 ft	>1,955 ft
Visitation Impacts	Only boater access available at Cedar and Hunter low water ramps; other shore visitation is decreased from lack of water access. Vegetation on exposed lakebed limits activity.	Primary ramp at Hunter is unavailable at 1942. Methodist boat ramp is inaccessible at 1935 and no access to the west end of the lake is available.	No access issues – All ramps open.	All boating access is available; shoreline use is limited to a few areas in coves, most beach access is gone.	Boat ramps become inaccessible; 100% of lake shore access closed.	Boat access is "Use at Own Risk" or out of marina slips.
Quality of Recreation Effects	Aesthetic values decrease dramatically as exposed shorelines grow. Boating safety is a high concern for all visitors due to increase of unmarked underwater hazards.	Safety becomes an issue for remaining boaters; hazards begin to surface. All coves close off that are not maintained by dredging.	No impacts	Jetties at Methodist begin to go under water. Patterson and Gremlin jetties go underwater.	Safety becomes an issue for visitors, jetties are all under water.	Lake is use at own risk.

¹ The information in this table was developed with input from USACE and NGPC staff familiar with Harlan County Reservoir. Lake elevations are in NGVD 1929.

Table 134. Percent of Reservoir Impacted by Critical Lake Elevation Thresholds

Lake Elevations	<1,933 ft	1,933-1,942 ft	1,942-1,948; multi-purpose pool is 1,945.7 ft	1,948-1,952 ft	1,952-1,955 ft	>1,955 ft
Water-based Visitor Impacts	100%	40%	0%	50%	75%	100%
Shore-based Visitor Impacts	0%	0%	0%	50%	75%	100%

¹ The information in this table was developed with input from USACE and NGPC staff familiar with Harlan County Reservoir. Lake elevations are in NGVD 1929.

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6.2. Future Without Project Conditions

This section considers the impact of future conditions on recreation, including sediment, water surface elevations, water quality and fishery conditions. Qualitative methods only were used to assess the effects of harmful algal blooms, water quality issues, habitat availability, and changes to reservoir fisheries on recreation at reservoirs that were not modeled and assessed quantitatively. The information used to qualitatively assess recreation was based on research, documents, information from subject matter experts, and data generated prior to the study or during the study (e.g., projected sedimentation in reservoirs; assessments of reservoir fisheries).

Because USACE sediment modeling indicated very few impacts to future sediment conditions and because no H&H modeling was conducted for Harlan County Reservoir, FWOP recreation impacts from sediment and changes in water surface elevations were evaluated qualitatively for this reservoir.

6.2.1.1. Recreation Facilities and Visitation

USACE will continue to operate and maintain the existing recreation facilities at Harlan County Reservoir with the exception of the marina which is privately operated. Visitation during average water years will be similar to the visitation under baseline conditions (921,938 visitors annually). Special events will continue to be hosted at the reservoir similar to past special events.

Harlan County Reservoir is expected to continue a similar water level fluctuation pattern as irrigation to meet farmland requirements both above and below the reservoir will remain of upmost importance. The impacts associated with conditions when Harlan County Reservoir is at low pool elevations will occur including reduced connectivity with cove habitat and impacts to reservoir fisheries. Issues related to high water levels will also occur during these conditions including excessive shoreline erosion and damage to infrastructure and boating access developments.

6.2.1.2. Sport Fisheries

Priority management species could change over time dependent on monitoring and survey results and changes to angler preference. USACE and the Nebraska Game and Parks Commission will continue to prioritize aquatic habitat projects similar to those at Gremlin, Patterson, and Methodist Coves which include bank stabilization, protection breakwaters, dredging, and angler access improvements. Invasive species will continue to be an issue posing a potential threat to aquatic resources, infrastructure, and recreational opportunities in the reservoir. Nebraska Game and Parks will continue to monitor and conduct outreach/education efforts to minimize future introductions of invasive species. Management activities will also continue in the future including stocking fish, evaluating fish population surveys, conducting aquatic-based research, improving and maintaining aquatic habitat, and improving and maintaining angler access and providing law enforcement.

Despite the challenges discussed here, Harlan County Reservoir provides valuable benefits to both humans and fish and wildlife. The Nebraska Game and Parks Fisheries Division will remain committed to managing aquatic resources at Harlan County Reservoir including but not limited to stocking fish, evaluating fish population surveys, conducting aquatic-based research, improving and maintaining aquatic habitat, improving and maintain angler access and providing law enforcement.

6.2.1.3. Effects of Sediment, Flooding, and Drought Conditions on Recreation

The effects of sediment on recreation at Harlan County Reservoir will be similar to past conditions with only minor localized effects by sediment issues. The shorelines surrounding the reservoir will continue to erode and sedimentation will cause further closure of the natural coves making access to these coves during low water periods difficult to impossible for both fish and boats. Sediment will continue to
accumulate in Lovewell Reservoir with an expected additional 1.6 % loss of the multipurpose pool over the next 25 years (2049) and 2.5% loss over the next 50 years (2074) (Appendix D).

Conditions similar to past droughts water levels will be similar to past periods of drought resulting in drops in visitation. Boating access and shifts in usage will continue to occur and be a challenge. Impacts to recreation can occur when reservoir elevations are below top of multipurpose pool with reduced boating access and limited water recreation and limited to no boating access when elevations are 12 feet below top of multipurpose pool. Safety also becomes an issue during these conditions from underwater hazards. Aesthetic values decrease dramatically as exposed shorelines grow. With climate change these decreases in visitation could be more frequent and prolonged leading to longer effects to recreation in the future.

Harlan County Reservoir has experienced impacts during past flooding events with higher pool elevations that caused impacts to recreation and damages to recreation infrastructure. These impacts are expected to continue in the future at Harlan County Reservoir during high flood pool conditions. Impacts from reduced access for boating and shore-based recreation start at approximately three to seven feet above top of multipurpose pool and above ,1955 feet boaters can access the reservoir but it is at their own risk or from the marina as boat ramps are inaccessible. Shore-based access is also closed at approximately seven feet above top of multipurpose pool During periods when the reservoir reaches the critical lake elevations for recreation the impacts (high and low) described in Table 133 and Table 134 to water-based and shore-based visitors are likely to occur with impacts to recreation leading to economic effects in the state and the region. With expected climate prediction of more frequent extreme flood events this may lead to more frequent impacts to recreation and damages to recreation infrastructure.

There are some HAB impacts at Harlan County Reservoir. Health alerts have been issued at the reservoir twice in the past ten years, in 2013 and 2019. The average concentration of microcystin typically peaks in early July before releases from the reservoir increase for downstream irrigation needs (Boyer, 2021). HABs are not considered an ongoing issue at Harlan County Reservoir, despite the lake having high nutrient levels compared to lakes in Kansas. Most blooms are short lived and can be shifted quickly by wind gusts or flushed out by irrigation releases. When HAB blooms do occur, appropriate signage is posted in affected areas. Lake managers have indicated that they observe lower visitation during HAB events. Water quality at Harlan County Reservoir and expected future conditions related to water quality are included in Appendix G. Impairments associated with excessive total phosphorus and total nitrogen concentrations will continue. HABs will continue in the future from cyanobacteria blooms causing potential warnings during the recreation season. Climate is a fundamental driver of nutrient and sediment transport and expected future climate conditions will directly impact transport from land surface to streams and reservoirs.

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