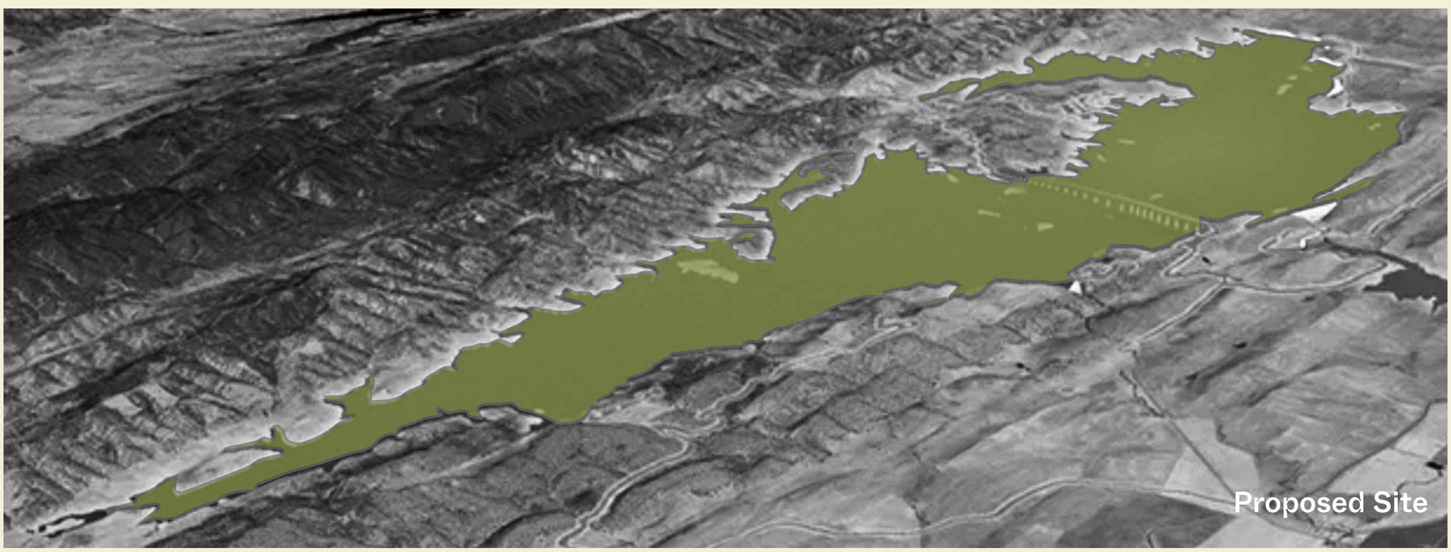
Estimate of Greenhouse Gas Emissions for the **Proposed Sites Reservoir Project** using the All-Res Modeling Tool



Prepared by Tell The Dam Truth and Friends of the River
Funded by Patagonia

Executive Summary

The Proposed Sites Reservoir project in northern California would divert water out of the Sacramento River to fill a 1.5 million acre-foot reservoir to serve as municipal water supply for agencies in northern and southern California. The project has generated both support and opposition, as well as controversy.

At the same time, knowledge and science about the environmental impacts of dams and reservoirs has increased significantly in the U.S. and across the planet, with a focus on the greenhouse gas (GHG) emissions caused by dams and reservoirs, especially methane.

In this report, we apply a newly developed tool, "All-Res", to estimate the life cycle GHG emissions from the Sites Reservoir project. The All-Res modeling tool is an advancement over existing modeling tools used to estimate GHG emissions from reservoir systems because All-Res includes all of the cradle-to-grave greenhouse gas emission source categories documented in peer-reviewed scientific literature attributable to dam and reservoir systems including hydropower facilities.

The Sites Project is **estimated to emit approximately**

362,000

METRIC TONS OF CO_2E/YEAR

The Sites Project will emit* approximately **the same as**

80,653

GAS-POWERED AUTOMOBILES DRIVEN FOR ONE YEAR, OR,

405,985,051

POUNDS OF COAL BURNED IN ONE YEAR, OR,

45,679

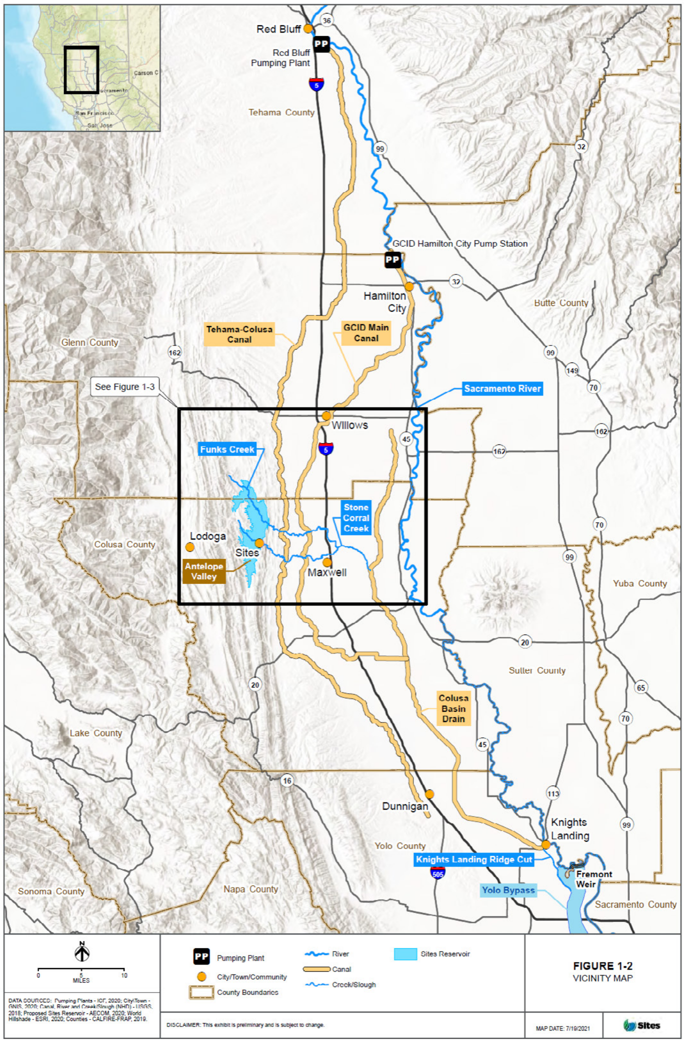
HOMES' ENERGY USE FOR ONE YEAR.

*using the U.S. EPA's emissions comparison tool

Further, the EPA requires large facilities to report if their emissions exceed 25,000 metric tons of CO_2e/year. Further yet, the most significant GHG emitted by the Sites Reservoir (and all reservoirs) is methane, a potent contributor to short-term climate change targeted by both the State of California and the U.S. Government as needing to be mitigated and decreased.

We strongly encourage decision-makers and public agencies to consider the GHG emissions caused by the proposed Sites Reservoir project in any ongoing or future permitting and funding decisions.

Figure 1: Vicinity Map, Sites Reservoir Project, California.



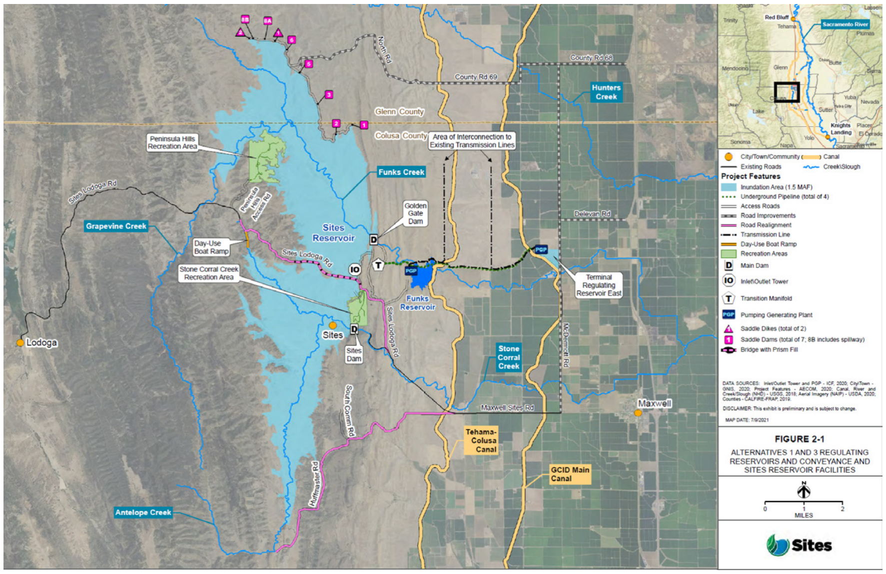
Introduction

Over the last few decades, dam and reservoir projects have come under increasing scientific scrutiny because of the greenhouse gases they emit. Dozens of scientific studies have found that dam and reservoir projects, including hydropower, can emit varying levels of greenhouse gases (GHGs), and sometimes even projects built primarily for hydropower production can emit even more GHGs than coal-fired powerplants producing an equal amount of electricity.[1,2,3,4]

Further, in 2022 for the first time in history, the U.S. Environmental Protection Agency reported dam and reservoir emissions to the United Nations Framework Convention on Climate Change, using IPCC guidelines, thus setting the precedent for these reports across the U.S. during dam permitting processes.[5]

Using readily available emissions models that estimate GHGs from hydropower projects, and using data provided from public sources including the Revised Draft Environmental Impact Report/Supplemental Draft Environmental Impact Statement for the proposed Sites Reservoir (USBR, 2021), we developed and applied the All-Res Modeling Tool[6] to calculate the total carbon footprint over the lifecycle of the Sites Reservoir Project, located in northern California.

Figure 2: Sites Reservoir Facilities



1 https://www.climatecentral.org/news/hydropower-as-major-methane-emitter-18246
2 https://www.washingtonpost.com/news/energy-environment/wp/2016/09/28/scientists-just-found-yet-another-way-that-humans-are-creating-greenhouse-gases/
3 https://www.latimes.com/science/la-xpm-2013-aug-01-la-dams-greenhouse-gas-hot-spots-20130801-story.html
4 https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0161947
5 https://therevelator.org/dam-emissions-reporting/
6 https://savetheworldsrivers.org/all-res/

The Sites Reservoir Project includes an off-stream reservoir to capture additional water from major storms and store the water until it is proposed to be used. Water would be diverted and pumped from the Sacramento River into two existing canals located in the northern portion of the Central Valley (**Figure 1**). The diverted water would be pumped into the reservoir from one or two pumping plants (**Figure 2**). The reservoir for the preferred alternative (Alternative 1) would inundate approximately 13,200 acres and hold up to 1.5 million acre-feet of water, withheld by two larger dams, seven smaller saddle dams, and two saddle dikes.

As stated on the Sites Reservoir website[7], the project would be operated in the following manner:

> Sites Reservoir is a "beneficiary pays" project, which means that the benefits of the project go to those paying. Each participant (including environmental uses) has control over their portion of the storage space and a proportionate share of the water diverted into Sites Reservoir. There is flexibility in the timing and uses of the water, including for the environment. The assurance of water being in the reservoir is largely the result of the individual participant decisions in their operations of their portion of the facility. This way, each member is assured to receive what they pay for in a way that works within and complements that member's water supply portfolio.

The project is to be owned and operated by the Sites Project Authority, composed of some Sacramento Valley public agencies[8]. The California Water Commission has allocated approximately $875 million in funds for the project,[9] including $44 million to pay for environmental review and permitting (to be approved on May 17, 2023),[10] and the U.S. Congress has appropriated approximately $214 million for the project as of 2022. [11] The U.S. Department of Agriculture is providing a $449 million loan.[11] The U.S. EPA has invited the Sites Project Authority to apply for a $2.2 billion low-interest WIFIA loan.[13]

7 https://sitesproject.org/frequently-asked-questions/
8 https://sitesproject.org/wp-content/uploads/2022/09/Sites-Joint-Powers-Agreement-1.pdf
9 https://cwc.ca.gov/Water-Storage/WSIP-Project-Review-Portal/All-Projects/Sites-Project
10 https://cwc.ca.gov/-/media/CWC-Website/Files/Documents/2023/05_May/May2023_Item_11_WSIPEarlyFunding_Final.pdf
11 https://sitesproject.org/wp-content/uploads/2023/01/Sites-Reservoir-News-Release_Additional-80M-Federal-Funds_1.4.2023.pdf
12 https://www.friendsoftheriver.org/wp-content/uploads/2018/12/Trump-officials-announce-450-million-loan-R-R-Searchlight-Nov-27-2018.pdf
13 https://www.acwa.com/news/sites-reservoir-to-pursue-wifia-loan/ https://www.epa.gov/wifia/what-wifia

THE ALL-RES MODELING TOOL

We applied the All-Res modeling tool for the Sites Reservoir project and compared total greenhouse gas emissions from the reservoir and its construction and operation over its life cycle to other emissions sources using the U.S. Environmental Protection Agency's emissions comparison calculator.

All-Res uses a cradle-to-grave, full life cycle inventory approach to calculate the total carbon footprint over the life cycle of a dam and reservoir system. The All-Res modeling framework uses a 100-year life cycle period, a common metric in greenhouse gas accounting for dam and reservoir facilities.

The All-Res modeling tool is an advancement over existing models used to estimate greenhouse gas emissions from reservoir systems because it examines the full, cradle-to-grave scope of the greenhouse gas emissions source categories documented in peer-reviewed scientific literature attributable to a dam and reservoir project. Existing tools examine only a portion of the lifecycle scope, leaving out emissions from end-of-life facility decommissioning, downstream biogenic emissions caused by the facility, carbon leakage, loss of ecosystem function, and significant fractions of land-use-change emissions.

The following emissions pathways are included in the All-Res modeling tool:

- Construction
- Facility operations and maintenance
- Facility decommissioning
- Reservoir surfaces
- Decay of organic matter on exposed banks of the reservoir
- Degassing methane through hydropower turbines and non-hydropower spillways

- Carbon leakage: land use changes away from the reservoir, including deforestation and vegetation changes, to replace inundated farmland and ranchland

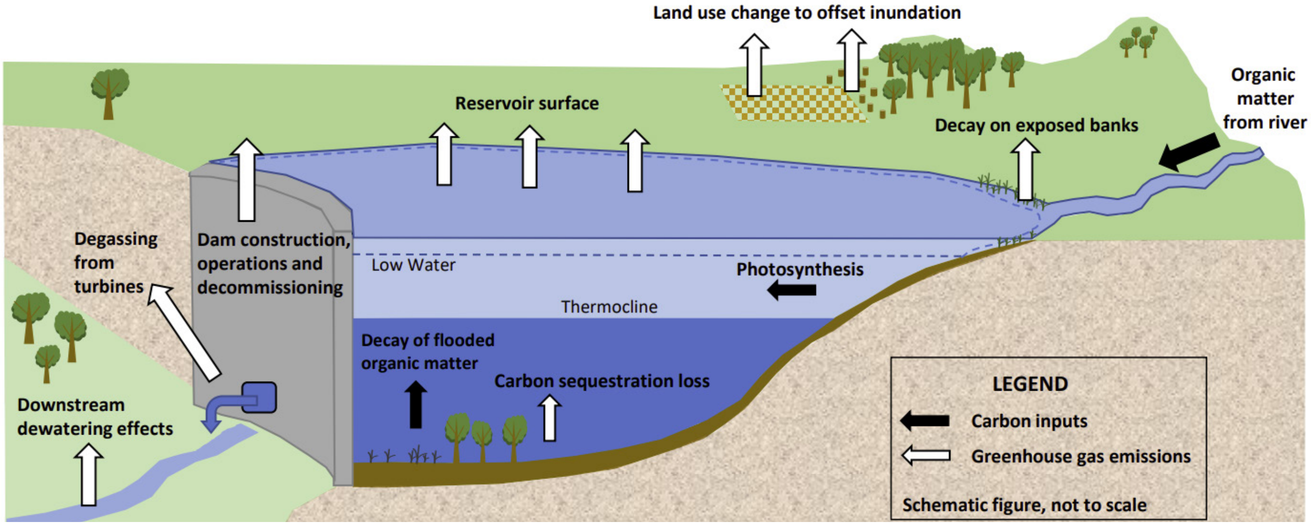
- Land use changes beneath the reservoir, including loss of carbon sequestration by vegetation that becomes inundated and emissions from anaerobic decay of that vegetation, as well as the lost ecosystem function of future carbon sequestration in the inundated former forest, and downstream effects, including ecosystem carbon loss from dewatering of wetlands, riparian areas, or mangroves, and emission releases from decaying riparian vegetation due to from fluctuating river levels.

Each of these are described below, including a summary of the key components and methods used to estimate the emissions from each pathway. See **figure 3**, below, for a graphical depiction of all emissions sources and pathways.

Per convention, All-Res estimates emissions for a 100-year evaluation period, and converts all methane (CH_4) and nitrous oxide (N_2O) emissions into CO_2e (carbon dioxide equivalent) emissions. N_2O emissions are calculated from ecosystem losses downstream, but are not quantified from reservoir surfaces or banks due to a lack of published data and models to account for those emissions.

The All-Res model also considers the quantified uncertainty of input data for all emissions pathways, and incorporates that into a Monte Carlo uncertainty analysis to estimate emissions confidence intervals. As more data becomes available and simulation models improve, this uncertainty will likely be reduced compared to the current version of this modeling tool.

Figure 3:
Emissions pathways in a dam and reservoir facility included in All-Res.



EMISSIONS PATHWAYS INCLUDED IN THE ALL-RES MODELING TOOL

Construction

Construction is a component of total emissions associated with reservoirs due to the large amount of energy required to heat limestone, clay, and cement to create the concrete that is used in construction, as well as the fuel burned in construction equipment on site and to quarry and deliver rock and aggregate used in dam construction. CO_2 emissions associated with the proposed Sites Reservoir construction that are in the All-Res modeling tool are taken directly from the Draft Environmental Impact Statement[14] (DEIS).

Operations and Maintenance

Emissions from Operations and Maintenance (O&M) activities at the Sites project include maintenance activities, use of recreational areas around the reservoir, and boating on the reservoir. Emissions in this pathway also include those associated with the electricity required to pump water into the supply canals and up into the reservoir, emissions associated with distribution and transmission of electricity, and then subtracting the electricity that is generated by the project. As with the construction pathway, emissions from the O&M pathway are taken from the DEIS.

California has enacted legislation to reduce greenhouse gas emissions 40% below 1990 levels by 2030, and an 80% reduction by 2050. Project construction is planned to be completed by 2029 with O&M to begin in 2030. The project proponents are planning net zero emissions by 2040, for ongoing O&M, by implementing a series of greenhouse gas reduction measures. Fossil Fuel emissions associated with O&M activities are computed only for the 2030-2040 period.

Decommissioning

Decommissioning of a reservoir has the potential to produce a significant amount of both CH_4 and CO_2 from the mineralization and decomposition of carbon present in exposed lakebed sediments. Pacca[15] estimated that emissions associated with decommissioning were an order of magnitude larger than emissions during the life of a large U.S. reservoir. Song et al[16] provides a

14 https://sitesproject.org/environmental-review/draft-environmental-impact-report-environmental-impact-statement/
15 Pacca, S., 2007. Impacts from decommissioning of hydroelectric dams: a life cycle perspective. Climatic Change, Vol 84 pp 281-294.
16 Song et al, 2018. Cradle-to-Grave Greenhouse Gas Emissions from Dams in the United States of America. Science, Elsevier. www.sciencedirect.com/science/article/pii/S1364032118302235

range of emissions factors of CO_2e per MW-hour of power production, and these are adapted for use in this non-hydropower reservoir application. Emissions associated with decommissioning the pumping plants and associated power lines and other infrastructure are included for this pathway for the Sites project.

Reservoir Surface

Greenhouse gases from the reservoir enter the atmosphere from the surface of the water body. These gases come from decomposing organic matter that flows into a reservoir from its watershed, from vegetation and soils that become inundated, and from aquatic plants and algae that produce CH_4,CO_2, and N_2O. Diffusion and bubbling (ebullition) bring the gases that are not oxidized in the reservoir to the reservoir surface.

Due to the different processes involved in the production of various gases, the All-Res modeling tool conservatively limits surface emissions estimates to CH_4. Deemer et al.[17] provided an estimated CH_4 surface flux emissions for 75 reservoirs worldwide. For the Sites project we used the average flux of 28 reservoirs that were in the Temperate Region of the Deemer et al.[18] database, which is the geographic zone for the Sites project.

Exposed Banks

The shorelines (banks) of reservoirs are exposed when water levels fluctuate due to reservoir operations. The periodic exposure and subsequent inundation of the reservoir banks creates conditions that can produce CH_4 from vegetation present in this zone. The DEIS includes predicted reservoir surface areas each month based on modeled water levels in the reservoir. The area for exposed banks was taken as the difference between the maximum and minimum surface areas for the long-term simulated inflows. Harrison et al.[19] documented how reservoir surface fluctuation increases methane emissions from reservoir banks and surfaces, and Deemer et al.[20] provides an estimate of the CH_4 surface emissions per unit area of exposed banks, which is used in this modeling tool.

17 Deemer, Bridget R., John A. Harrison, Siyue Li, Jake J. Beaulieu, Tonya DelSontro, Nathan Barros, José F. Bezerra-Neto, Stephen M. Powers, Marco A. dos Santos, and J. Arie Vonk. “Greenhouse Gas Emissions from Reservoir Water Surfaces: A New Global Synthesis.” BioScience 66, no. 11 (November 1, 2016): 949–64. https://doi.org/10.1093/biosci/biw117.
18 Ibid 17.
19 Harrison, J. A., B.R. Deemer, M.K. Birchfield, and M.T. O’Malley. 2017. Reservoir Water-Level Drawdowns Accelerate and Amplify Methane Emission. Environmental Science & Technology 41: 1267-1277. https://doi.org/10.1021/acs.est.6b03185.
20 Ibid 8.

Turbines

Discharge of reservoir water through turbines or outlets, referred to here as the turbines pathway, can be a source of emissions. These emissions are due to degassing of methane-rich water discharged from the oxygen-depleted depths of the reservoir through the turbines. These emissions are released due to the rapid drop in hydrostatic pressure when water exits the turbine into the river/reservoir/canal downstream. Emissions of CH_4 are much higher for outlets that are situated below the thermocline, in the hypolimnion, due to the anoxic conditions present in those waters. Delwiche et al.[21] estimated that CH_4 emissions at outlets are likely 80 to 95 percent of surface emissions, which is consistent with other publications. A value of 80% of surface emissions has been used in the current version of All-Res on other projects.

The proposed Sites Reservoir is designed to have a multi-level inlet/outlet tower within the reservoir, from which water may be drawn from multiple depths ranging from near the surface to near the bottom. The depths from which the water would likely be drawn through the tower is not specified in the design documents. To take this uncertainty into account, we make the assumption that water may be drawn equally from below and above the thermocline, reducing the estimated emissions by half, to 40% of surface emissions.

Land Use Changes Under The Reservoir

Inundation of vegetated land beneath a reservoir affects greenhouse gas emissions in two pathways: the loss of ecosystem function as future carbon sequestration (uptake) from the vegetation had the reservoir not inundated the site, and the production of CO_2 due to decomposition of that inundated vegetation. These gasses are released through the reservoir surface and turbines but are included in this emissions pathway due to uncertainties in the release pathway to the atmosphere. The IPCC greenhouse gas inventory guidance (Penman et al.,[22] Lasco et al.,[23] and Lovelock et al.[24]) for estimating the carbon stock (mass), the changes in carbon stock, and the greenhouse gas emissions and removals associated with changes in land use are used for this pathway. Estimated inundation areas of oak woodlands, wetlands, grasslands – the vegetation in the proposed inundation area – were derived from the Sites Reservoir DEIS.

21 Delwiche et al, 2022. Estimating Drivers and Pathways for Hydroelectric Reservoir Methane Emissions Using a New Mechanistic Model. JGR Biogeosciences, 127, e2022JG006908.
22 Penman et al, 2003. Good Practice Guidance for Land Use, Land-Use Change and Forestry. IPCC National Greenhouse Gas Inventories Programme.
23 Lasco et al, 2006. Volume 5 Chapter 5, Cropland. 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
24 National Greenhouse Gas Inventories.

Land Use Changes Away From The Reservoir (Carbon Leakage)

"Carbon leakage" describes the change in CO_2 emissions that occur due to a land use change away from a reservoir to replace land uses in areas that were inundated. The most common example is the need to replace inundated farmland to match the food production prior to the loss of farmland due to inundation. For the Sites project it is assumed that the farmland losses are negligible, but accounts for replacing settlements, grasslands and forests. IPCC guidance (Penman et al.,[25] Lasco et al.,[26] and Lovelock et al.[27]) for estimating the changes in carbon stock due to changes in land use were used for this pathway. Estimated inundation areas of oak forests and settlements were provided in the DEIS.

Downstream Effects

A reservoir can affect emissions in downstream areas due to changes in river flow. Reservoirs typically decrease river flow downstream, which can have the effect of reducing and drying out of wetland and other riparian vegetation, causing a loss of ecosystem carbon and nitrogen through decomposition of dead plants and loss of soil organic carbon and nitrogen. This decomposition process produces CH_4, CO_2 and N_2O. In addition, hydropower reservoirs can affect downstream emissions due to fluctuating river levels caused by changes in the hydrologic flow regime. The latter effects may be similar to those for shorelines of reservoirs, with additional emissions produced due to the periodic exposure and subsequent inundation of the river banks.

No direct estimation of wetland loss in the Sacramento – San Joaquin River Delta is apparent in the DEIS analysis. We estimate that 3,686 acres of wetlands in the Sacramento River – San Joaquin River Delta would be impacted by the project. The term "impacted" means freshwater marsh, underlain with peat soils, that would no longer reliably receive flows that would sustain the hydrology of those soils in their native, anoxic state. The peat in the delta area is therefore assumed to decompose in the same ways that peat soils drained for agricultural production would decompose.[28, 29] The acreage estimate was arrived at by using the 1% overall

25 Ibid 13.
26 Ibid 14.
27 Ibid 15.
28 Huang et al, 2021. Tradeoff of CO2 and CH4 emissions from global peatlands under water-table drawdown. Nature Climate Change 11:618-622.
29 Eve et al, 2014. Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory. Technical Bulletin Number 1939. U.S. Department of Agriculture, Washington, DC. 606 pages.

reduction in total flows from the Sacramento River to the Delta based on modeled flows presented in the DEIS. The impacted wetlands assumes that half of the inflow to the Delta freshwater wetland of 737,295 acres[30] comes from Sacramento River. This estimate assumes an even ratio of stage to surface area in the region of river inflows to the Delta, for which no analysis is provided in the DEIS.

The DEIS discusses widespread ecosystem recovery and improvement projects in the region, however none of the projects are clearly described as “additional.” These are projects being implemented by the California Department of Water Resources (DWR) that are already in planning or implementation stages. For these projects to be classified as “additional” – meaning they would offset carbon emissions from loss of wetland in the Delta due to the proposed Sites project – they would have to be planned and implemented as a direct result of the Sites project. Freshwater wetland restoration requires additional flows be dedicated to restoring wetlands in total, and thus with a net loss of freshwater inflow to the Delta, it isn’t clear how any additional restoration activities could occur.

Uncertainty Analyses

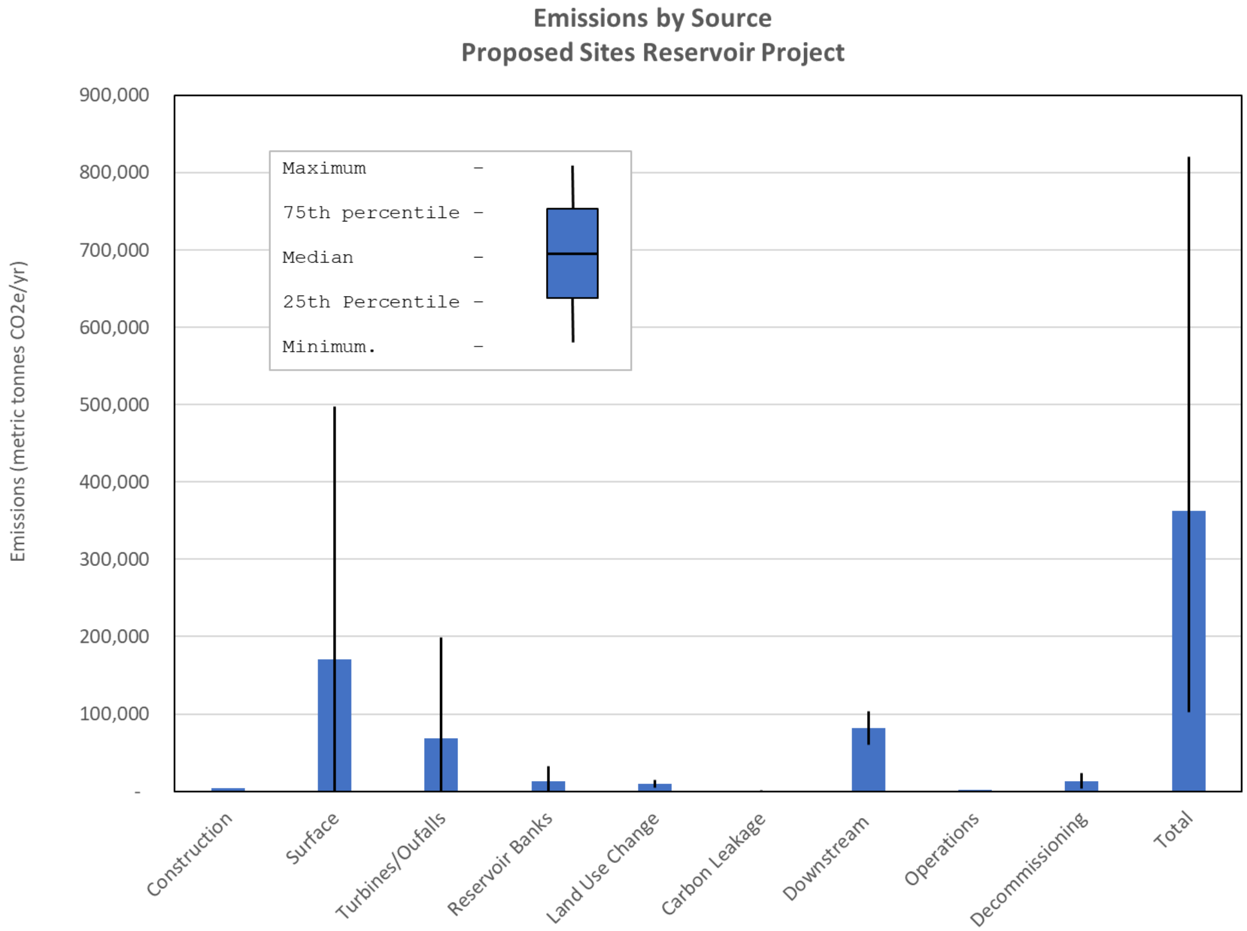
To account for uncertainty in the emissions models, the All-Res modeling tool includes an uncertainty analysis. The analysis uses a Monte-Carlo process that utilizes the published probability distributions of emissions factors, carbon stocks, and construction materials, based on published ranges and standard deviations, where provided. Using a 1000-iteration approach, the resulting emissions are described by their mean and percentile distributions which are presented in the model output. The uncertainty analysis was not applied to emissions associated with the Construction, nor to the Operations and Maintenance, pathways since emissions from those pathways were provided in the DEIS.

30 Young et al, 2021. Food Web Fuel Differs Across Habitats and Seasons of a Tidal Freshwater Estuary. Estuaries and Coasts 44, 286–301.

SITES RESERVOIR PROJECT RESULTS

The Sites Reservoir project is predicted to emit approximately 36.2 million metric tons of CO_2e over its 100-year lifecycle, or approximately 362,000 metric tons of CO_2e/year. The most significant emissions would be methane from the reservoir surface and turbines as well as carbon dioxide and nitrous oxide from the loss of ecosystem carbon in the wetlands of the San Joaquin-Sacramento River Delta. See **figure 4** below.

Figure 4:
Distribution of predicted emissions of CO_2e/year by emissions pathway for the Sites Reservoir Project over its 100-year lifecycle.



31 https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

For comparison, using the EPA's GHG emissions calculator, this amount of yearly emissions is equivalent to the emissions described in **Figure 5** below:

Figure 5:
Emissions Comparisons From EPA's Website

362,437 Metric Tons of Carbon Dioxide (CO_2) equivalent

This is equivalent to greenhouse gas emissions from:

80,653 gasoline-powered passenger vehicles driven for one year	929,124,940 miles driven by an average gasoline-powered passenger vehicle

This is equivalent to CO_2 emissions from:

40,782,829 gallons of gasoline consumed	35,602,849 gallons of diesel consumed
405,985,051 pounds of coal burned	4,798 tanker trucks' worth of gasoline
45,679 homes' energy use for one year	70,521 homes' electricity use for one year
1,998 railcars' worth of coal burned	838,293 barrels of oil consumed
16,650,020 propane cylinders used for home barbeques	0.097 coal-fired power plants in one year
0.911 natural gas-fired power plants in one year	44,087,795,796 number of smartphones charged

For further comparison, the U.S. Environmental Protection Agency requires that certain large emitters in the U.S. report under the EPA's Greenhouse Gas Reporting Program if their emissions equal or exceed 25,000 metric tons of CO_2e/year. **The Sites project's estimated emissions are over 14 times greater than the EPA's reporting threshold.**

Some proponents of the project point to the electricity generated by the project as a significant boon to its development. This argument has little merit because:

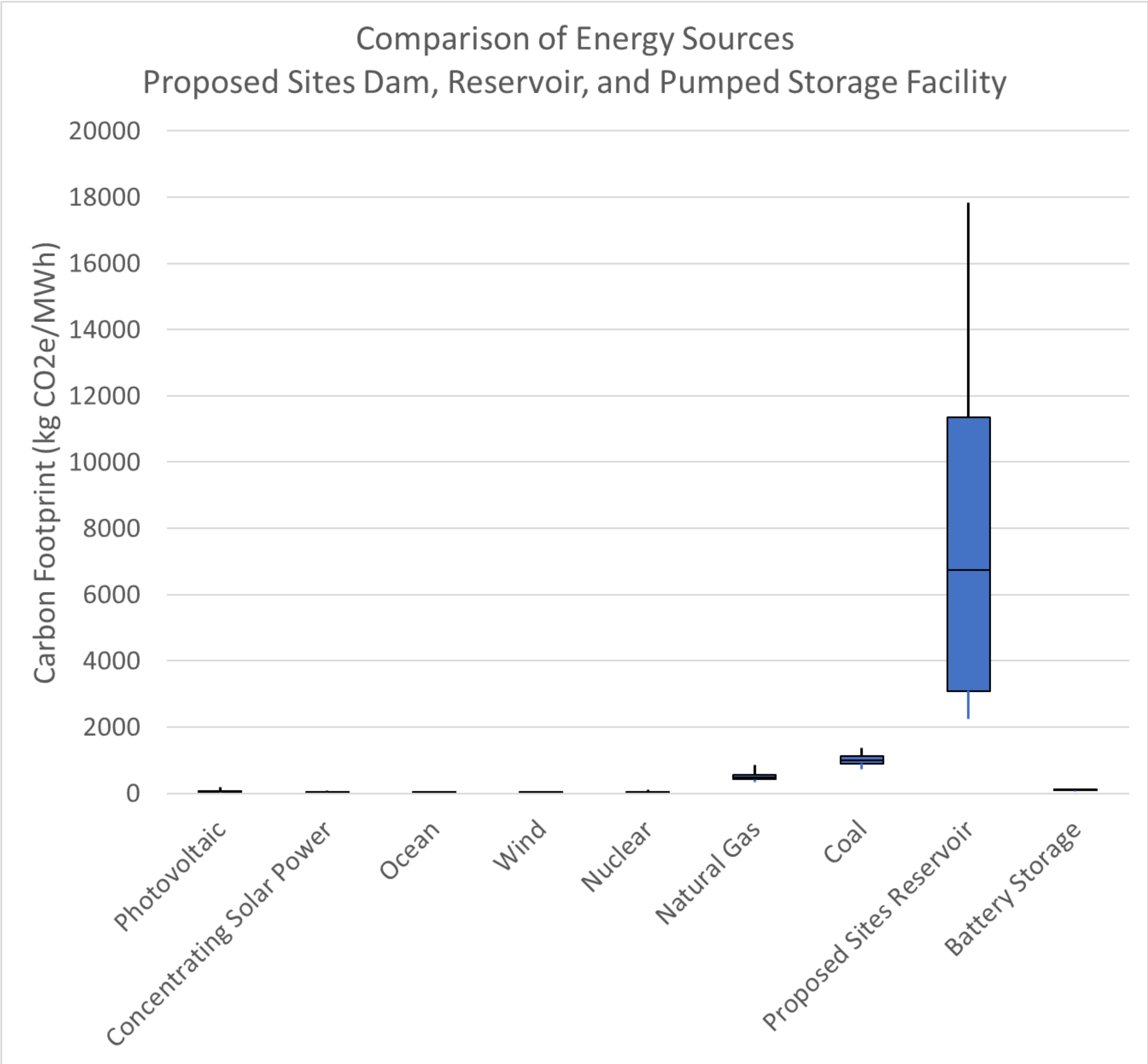
First, the project is estimated to generate only a small amount of electricity, up to 46 GWh of energy per year as a long-term average, and up to 74 GWh/year during dry and critically dry water years. For comparison, an average gas-fired powerplant produces 650 MWh/year.

Second, like all "pumped storage" facilities, the Sites project would require more electricity to pump the water out of the Sacramento River and into the canals, and then into the reservoir, than the project would generate through its turbines.

Third, if the greenhouse emissions attributable to the project by the All-Res Modeling Tool are compared to the emissions of other electricity generating sources, Sites would be an enormous emitter in a MWh/year comparison. The median emissions per MWh for Sites are estimated to be approximately 6,800 kilograms of CO_2e whereas a coal-fired powerplant is only 1,000 kilograms of CO_2e/MWh. See **Figure 6** below.

32 https://www.epa.gov/ghgreporting
33 https://www.eia.gov/todayinenergy/detail.php?id=38312#:~:text=Most%20of%20the%20installed%20capacity,600%20MW%20to%20700%20MW

Figure 6:
Emissions comparisons for Other Energy Sources



THE AUTHORS

Gary Wockner, PhD, is an award-winning environmental activist and author who directs Tell The Dam Truth. Gary has over two decades of experience protecting rivers in Colorado, the Southwest U.S., and across the world. He has written and lectured extensively for public audiences and the media about the greenhouse gas emissions caused by dams and reservoirs.

Mark Easter is an ecologist, retired from Colorado State University, where he worked for over two decades developing and implementing ecosystem greenhouse gas accounting methods and decision support systems for agriculture, forestry, wetlands, and other land uses. He has authored or co-authored more than fifty publications and contributed to multiple others in the field of ecosystem GHG accounting. Mark is a TTDT consultant.

Gordon McCurry, PhD, is a hydrologist with more than 35 years of experience with quantitative analyses and modeling of groundwater and surface water systems. He has been involved in evaluating the hydrologic effects of climate change for several decades, focusing on how changes in precipitation and temperature affect both water supply and water demand, and how water management practices need to adapt to our new hydrology. Gordon is a TTDT consultant.

Tell The Dam Truth (TTDT) fights the climate crisis by advocating for the protection and restoration of river ecosystem biodiversity and carbon sequestration. TTDT works to include all of the impacts of dams in all public decision-making around dam permitting, re-licensing, and decommissioning. TTDT receives funding and support from **Patagonia**.

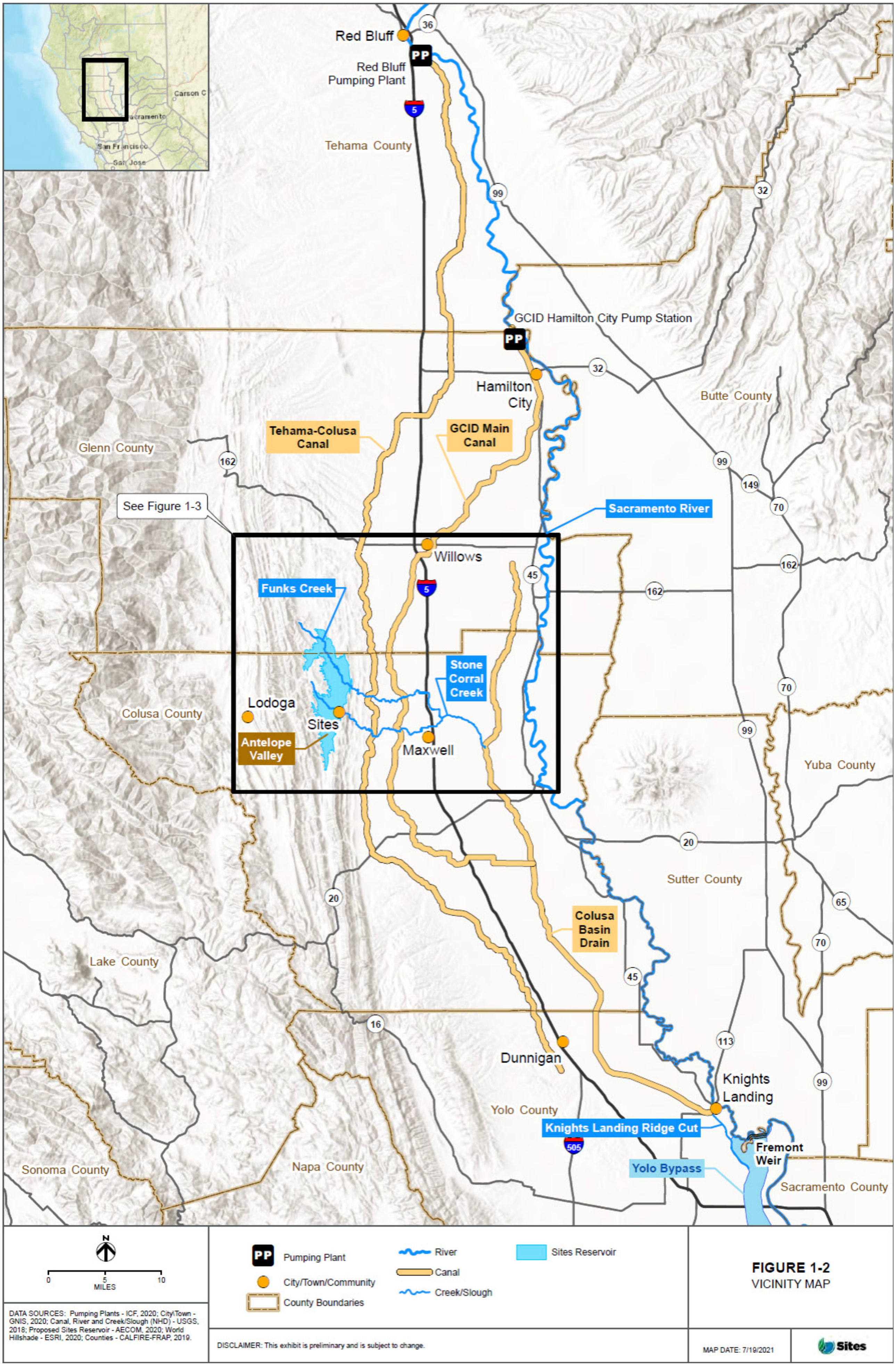
TELLTHEDAMTRUTH.COM

Friends of the River (FOR) is dedicated to preserving and restoring California's rivers, streams, and their watersheds as well as advocating for sustainable water management. Friends of the River was founded in 1973 during the struggle to save the Stanislaus River from New Melones Dam. Friends of the River is nationally recognized as an authority on the adverse impacts of dams on rivers and ecosystem. FOR has led successful campaigns for the permanent protection of many outstanding California rivers and streams. Friends of the River has 3,500 members, 7 staff, and a 10 member Board of Directors.

FRIENDSOFTHERIVER.ORG

PRINTABLE MAPS OF THE SITES RESERVOIR PROJECT

Figure 1: Vicinity Map, Sites Reservoir Project, California.



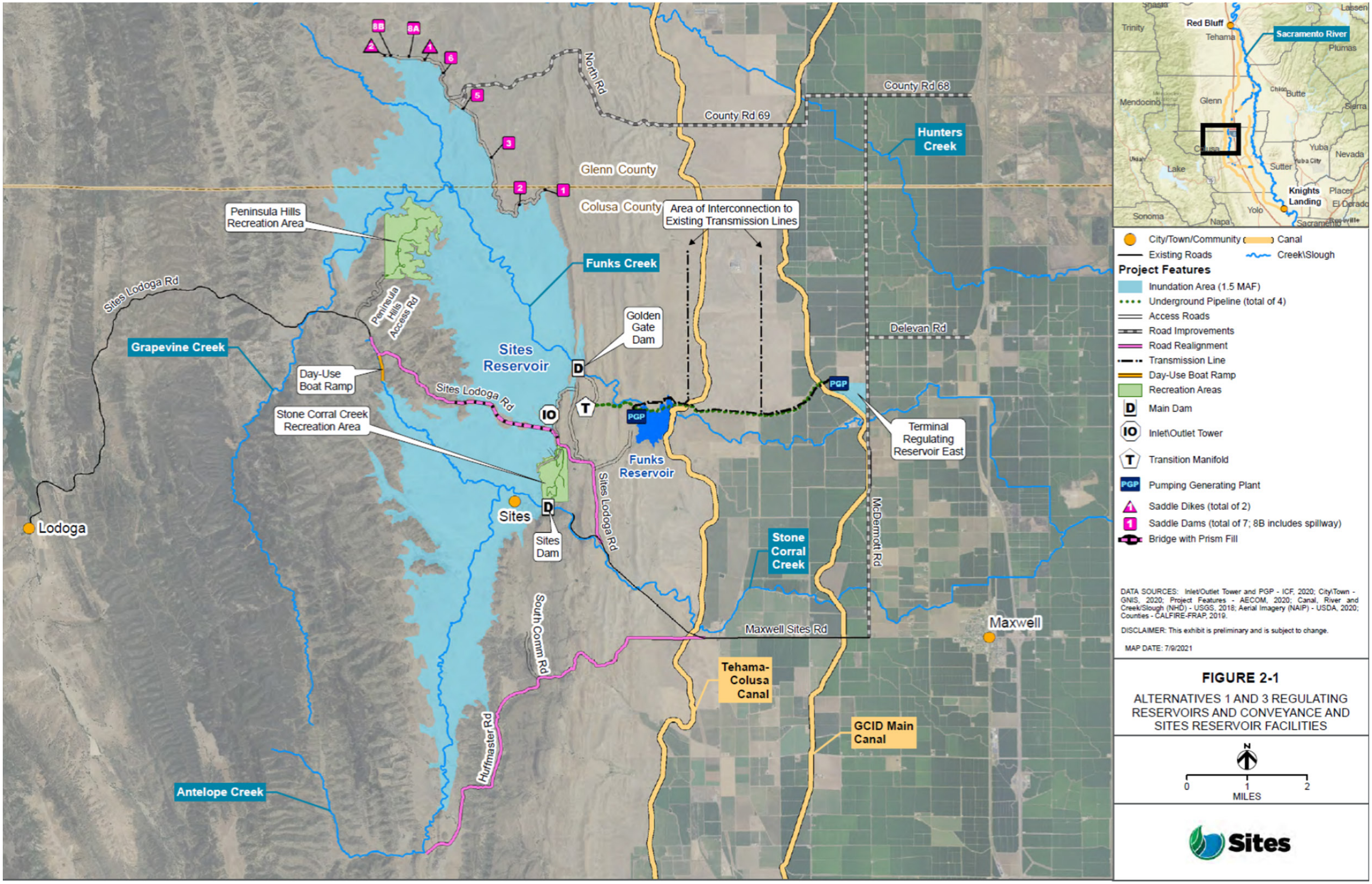


Figure 2: Sites Reservoir Facilities