November 8, 2022

Colbert Burnett
White Mountain Apache Tribe
P.O. Box 2110
White River, Arizona 85941

Dear Mr. Burnett:

The California Air Resources Board (CARB) has reviewed the applications for determination of Direct Environmental Benefits in the State of California (DEBS) that were submitted on December 22, 2021 by the White Mountain Apache Tribe and Spatial Informatics Group pursuant to the California Cap-and-Trade Regulation (Cal. Code Reg., tit. 13, § 95989). The applications for the two projects in the table provide a detailed report presenting evidence of the environmental benefits the projects provide to the State of California. The offset projects have demonstrated that the offset project operator, White Mountain Apache Tribe, has committed to certain forest management activities to improve water quality and quantity to California. Although these management activities take place on forestland outside of California, the project lands are located within the watersheds of the Little Colorado River and Salt River, which supply water to the Colorado and Gila Rivers and ultimately to California. The applications demonstrate that the offset projects provide for the reduction or avoidance of pollutants that are not credited pursuant to the 2011/2014 Compliance Offset Protocol U.S. Forest Projects and that could have an adverse impact on waters of the State. CARB staff has determined that both White Mountain Apache Tribe IFM projects in the table provide DEBS.

CARB Project ID	Project Name	DEBS to California
CAFR5072	White Mountain Apache Tribe Forest Carbon Project	Yes
CAFR5253	White Mountain Apache Tribe Forest Carbon Project II	Yes

If you have any questions regarding this response, please contact Shelby Livingston, Manager, Program Operation Section, via email at Shelby.Livingston@arb.ca.gov.

Sincerely,

Rajinder Sahota, Deputy Executive Officer

Enclosure

cc: Matt Botill, Chief, Industrial Strategies Division

Mark Sippola, Branch Chief, Climate Change Program Evaluation Branch

Wesley Dyer, Attorney

Shelby Livingston, Manager, Program Operation Section

APPLICATION FOR DIRECT ENVIRONMENTAL BENEFITS STATUS

CARB STAFF USE ONLY

CARB Form Tracking Number:	Date Received:	Date Processed:
Date Reviewed:	Date Revisions Requested:	Date Approved:

PART I: OPO/APD CONTACT

The person completing this form should be an Offset Project Operator (OPO), Authorized Project Designee (APD), or holder of offset credits employee or representative and may differ from the Compliance Instrument Tracking System Service (CITSS) account representative signing the form. This contact person is the person California Air Resources Board (CARB) staff will contact with any questions regarding this application.

Contact Person: Colbert Burnett (OPO) & Erin Alvey (Technical Consultant to OPO) (please include both folks in communications)	
Telephone Number: Colbert: (928) 338-2477 ; Erin: (808) 344-7004	Email Address: Colbert: ColbertBurnette@wmat.us; Erin: ealvey@sig-gis.com

PART II: OFFSET PROJECT INFORMATION

Offset Project Name: White Mountain Apache Tribe Forest Carbon Project II	
OPR Project ID#: ACR303	CARB Project ID # (if applicable): CAFR5253
Offset Project Operator (OPO): White Mountain Apache Tribe	Authorized Project Designee (APD): -

Offset Project Registry Listing Project:

- ☑ American Carbon Registry
- ☐ Climate Action Reserve
- ☐ Verra

Compliance Offset Protocol:

☐ Livestock Projects	☐ Rice Cultivation
☐ Mine Methane Capture Projects	☑ U.S. Forest Projects
☐ Ozone Depleting Substances Project	☐ Urban Forest Projects

Compliance Offset Protocol Version:

- ☐ October 20, 2011
- ☐ April 25, 2014
- ☑ November 14, 2014
- ☐ June 25, 2015

PART III: ENVIRONMENTAL BENEFITS DOCUMENTATION SUMMARY

Summarize the documentation supporting this application for determining that this project has Direct Environmental Benefits in California, including a list of all data, information, and reports. Specify which provision(s) in section 95989(b) (1)-(3) of the Cap-and-Trade Regulation is being relied on for this application. Attach all documentation to this form.

Please see the attached prepared summary report, which contains all supporting documentation demonstrating the Direct Environmental Benefits provided by the White Mountain Apache Tribe's forest carbon projects to the State of California. Note that one report total is being submitted for WMATs two projects being considered for DEBS Status, per verbal guidance from ARB (Stephen Shelby, Shelby Livingston, and Nora Kennedy on 11/05/2021 call). These two Compliance IFM projects have the same OPO/landowner, are geographically adjacent, and fall under the same forest management plan.

PART IV: OPO SIGNATURE WMAT FOREST CARBON PROJECT II

In signing this form, I certify under penalty of perjury of the laws of California that the information contained in this form is true, accurate, and complete. I further certify that I am an Account Representative of the (OPO) or holder of offset credits.

Signature: Colbert G. Burnette	Printed Name: COLBERT G. BURNETTE
Title: TRIBAL ENGINEER	Date: DECEMBER 22, 2021

Literature Review in Support of the Direct Environmental Benefits in the State of California Application for the White Mountain Apache Tribe

DECEMBER 2021

PREPARED FOR

White Mountain Apache Tribe

PREPARED BY

SWCA Environmental Consultants

LITERATURE REVIEW IN SUPPORT OF THE DIRECT ENVIRONMENTAL BENEFITS IN THE STATE OF CALIFORNIA APPLICATION FOR THE WHITE MOUNTAIN APACHE TRIBE

Prepared for

White Mountain Apache Tribe
P.O. Box 700
Whiteriver, Arizona 85941
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SWCA Project No. 69334

December 2021

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INTRODUCTION

The White Mountain Apache Tribe (WMAT), which resides within the Fort Apache Indian Reservation, has developed two improved forest management (IFM) carbon projects intended to improve the health and function of the forestlands. WMAT's two current IFM carbon projects provide Direct Environmental Benefits (DEBS) to the quantity and quality of the State of California's water resources. Pursuant to California State Assembly Bill 398 (AB 398; Chapter 135, Statutes of 2017), carbon offset projects that qualify for a positive DEBS flag contribute to "the reduction or avoidance of emissions of any air pollutant in the state or the reduction or avoidance of any pollutant that could have an adverse impact on waters of the state." In compliance with Section 95989(b) of the Cap-and-Trade Regulation, as well as the criteria outlined in the 2011 and 2014 compliance offset protocols for U.S. Forest Projects, WMAT demonstrates thoughtful management of these forests in a landscape that contains the headwaters of major contributing tributaries to the Colorado River, an important water source for California. The DEBS claims presented in this report for these projects are based on scientific, peer-reviewed literature and government publications. These DEBS highlight co-benefits of WMAT's IFM projects that are additional to the formal greenhouse gas reductions credited under the CARB's Compliance Offset Protocol (CARB 2021a, 2021b).

As noted on the California Air Resources Board (CARB) website, healthy forests that are subject to IFM (such as those in WMAT's two carbon projects) or Avoided Conversion projects (i.e., preventing the loss of forest to a non-forest use) reduce the risk of polluted runoff into waters of the State (CARB 2017, 2021c). A properly functioning watershed has numerous benefits, such as lower nutrient and sediment concentrations within water flowing from undisturbed forested watershed, compared with flows from watersheds affected by significant disturbances such as severe wildland fire and insect and disease outbreaks or watersheds that are dominated by urban or agricultural land uses (Ice and Binkley 2003; MacDonald and Stednick 2003; Ryan and Glasser 2000).

Water is a fundamental but limited resource in the semi-arid West. Approximately 4.4 million acre-feet of southern California's public water supply is provided by the Colorado River (Water Education Foundation 2021), which is supplied by tributaries that originate in the forested mountains of Arizona and four other western states (The Nature Conservancy of California 2012). Arizona forestland, including lands within the Fort Apache Indian Reservation, ranges from high-elevation alpine forests to lower-elevation piñon pine and riparian forests. These forestlands facilitate California's water supply through a multitude of ecosystem services that protect downstream water quantity and quality, including mitigating soil erosion and sedimentation, filtering contaminants, enhancing soil moisture storage and groundwater recharge, storing snowpack that sustains runoff during the summer, and reducing the likelihood of flooding by protecting and maintaining plant communities (Hamilton 2008; U.S. Environmental Protection Agency [EPA] 2015). Thus, WMAT's actions under the Cap-and-Trade Regulation IFM protocols provide direct benefits to the quality and quantity of California's waters.

WMAT IFM Projects

Water is an important resource to the WMAT, as expressed in the Tribe's Forest Management Plan which states that

> T'u (water) is one of the gifts of the Creator that is essential to the survival of the White Mountain Apache People. Water is inseparable from the land and culture. The Apache homeland has always been blessed with a great number of springs, streams, and meadows to sustain a diverse and vibrant community of plants, wildlife, and people. (Williams et al. 2005: 87)

This philosophy illustrates the incredible importance of water to the Tribe, both ecologically and culturally. WMAT has endeavored to protect this natural resource through the adoption of Water Quality Protection Ordinances; designation of Water Management Emphasis Areas; and establishment of best management practices, logging restrictions, and other forest management guidelines. The Tribe's recognition of the sacredness of water guides their efforts for their IFM carbon projects, as well.

The Fort Apache Indian Reservation stretches across 1.68 million acres in Eastern Arizona (Figure 1). These lands encompass approximately 400 miles of clean-running rivers and streams, plus over 26 lakes, that collectively form the headwaters of the Little Colorado and Salt Rivers. These local river systems are key contributors to the larger Colorado River system. The good health of these waterways is evidenced by the ability of the WMAT and its partners to bring back the Apache trout (*Oncorhynchus apache*) from the brink of extinction. Part of this success has been WMAT's ability to manage the local watersheds on a landscape scale following IFM protocols.

The Bureau of Indian Affairs (BIA) Fort Apache Agency and WMAT have been leaders in the use of fuel reduction treatments such as prescribed burning in Indian Country since the 1950s. Between 1950 and 2017, more than 882,000 acres were treated on the Fort Apache Indian Reservation, primarily for hazardous fuel reduction (BIA Fort Apache Agency 2017).

Two WMAT IFM carbon projects are enrolled under California's Cap-and-Trade Program (Table 1). The projects span a total of 210,000 acres across both the Little Colorado and Salt subregional watersheds, which are both part of the Lower Colorado regional watershed (Hydrologic Unit Code [HUC] 15).[1] The goal for both carbon projects is to increase and conserve forest carbon stocks through the implementation of sustainable forest management (SIG Carbon 2021). Such practices include active fire and fuels management, cultural resource conservation, and targeted commercial harvest that commits to sustained yield and supports local tribal economies (BIA Fort Apache Agency 2015; Williams et al. 2005).

Table 1. Summary of WMAT IFM Carbon Projects

Project Name	CARB Project ID	Applicable Compliance Offset Protocol Version	HUC-4 Watersheds	Acreage
WMAT Carbon Project 1	CAFR5072	2011 Forest Protocol (CARB 2021a)	Salt (HUC 1506)	90,000
WMAT Carbon Project 2	CAFR5253	2014 Forest Protocol (CARB 2021b)	Little Colorado (HUC 1502) and Salt (HUC 1506)	120,000
			TOTAL	210,000

[1] For the purposes of this analysis, the term "watershed" is used for multiple watershed levels, including regional (HUC-2) and subregional (HUC-4) watersheds, with the level specified as needed.

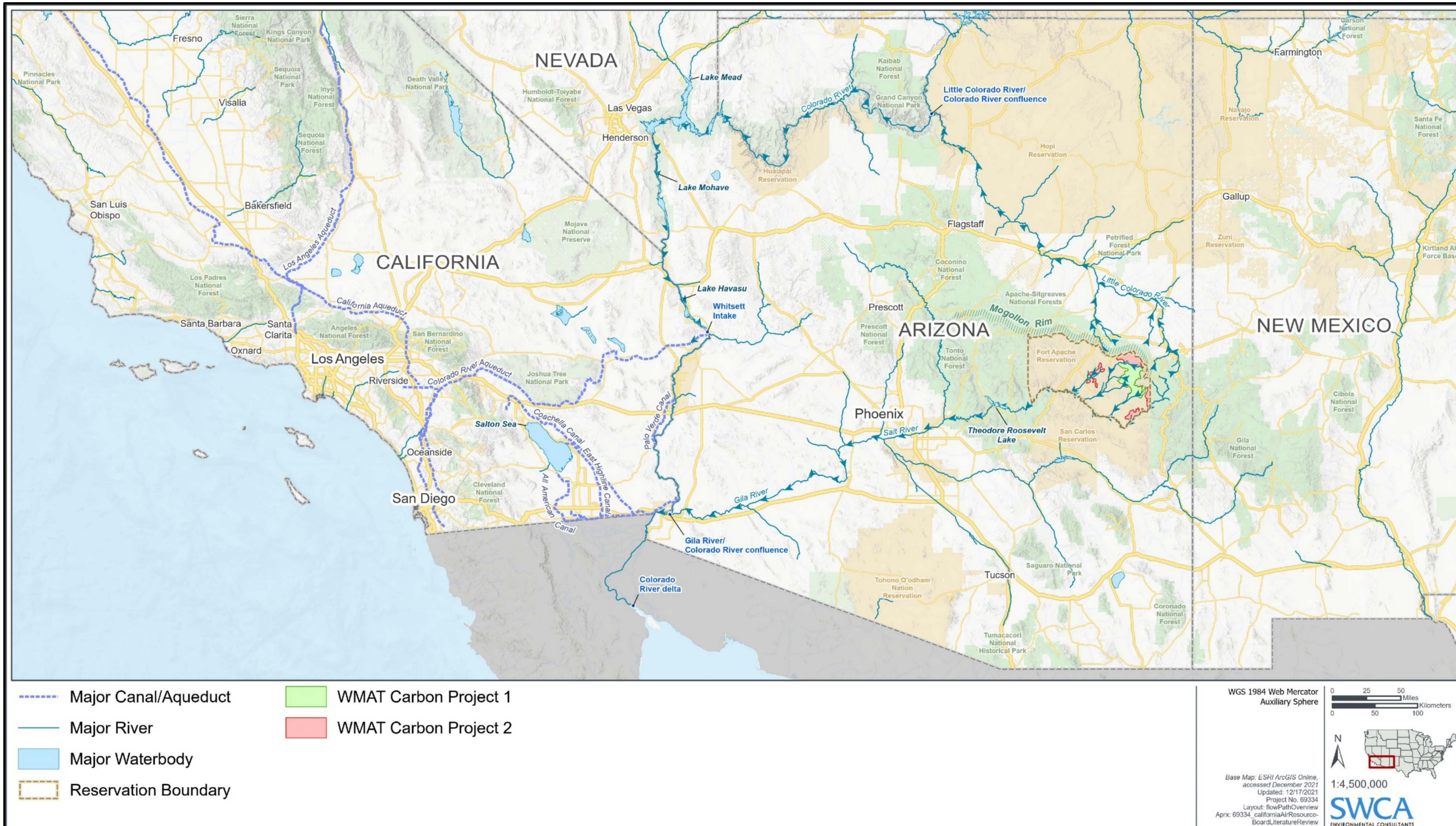

Figure 1. Hydrologic connection between WMAT IFM carbon projects and California waters.

HYDROLOGIC CONNECTIONS AND PATHWAYS

WMAT's two IFM carbon projects encompass a combined 210,000 acres within watersheds that directly impact California's water supply and integrity (see Figure 1). These forest management areas lie partially in the Salt subregional watershed (HUC 1506) and partially in the Little Colorado subregional watershed (HUC 1502), both of which encompass headwaters that feed into the Colorado River. Thus, the WMAT carbon projects' activities are taking place at the very headwaters of each system, and the benefits of managing the forest carbon projects transmit themselves to downstream waters through their numerous physical, chemical, and biological connections, as established in the scientific literature. Specific ecological connections of particular importance are further described in this report.

Importance of Headwaters to Watershed Health

The scientific community has long recognized the importance of stream headwater systems to the health of ecological communities downstream. The interconnections described by the body of scientific literature are numerous and detailed. In early 2015, in response to a 2007 Supreme Court ruling involving the Clean Water Act,[2] the EPA Office of Research and Development published a review and synthesis of more than 1,200 publications from peer-reviewed scientific literature (EPA 2015). The goal of the EPA review was to explore the connectivity of streams and wetlands to downstream waters.

The EPA (2015) drew the following major conclusions from their synthesis and review; these are relevant to the DEBS of the WMAT IFM carbon projects:

- All tributary streams, including perennial, intermittent, and ephemeral streams, are physically, chemically, and biologically connected to downstream rivers via channels and associated alluvial deposits where water and other materials are concentrated, mixed, transformed, and transported.
- That wetlands and open waters in riparian areas and floodplains are physically, chemically, and biologically integrated with rivers. They serve functions that improve downstream water quality, such as assimilation, transformation, or sequestration of pollutants (nutrients, pesticides, or metals, for example), and provide an integral component of river food webs.
- Aside from wetlands and open waters directly associated with streams in the floodplain, more removed wetlands (such as wet meadows and ponds) also play important roles in downstream waters, including storage of floodwater, recharge of groundwater that sustains river baseflow, retention and transformation of contaminants, and providing habitats needed for stream species.
- These various connections happen at multiple time scales, including low-frequency, high-magnitude events (like large flood pulses in ephemeral streams), as well as high-frequency, low-magnitude events (sustained or seasonal baseflow in perennial streams).

Ultimately, the EPA review concludes that the cumulative actions across the entire upstream contributing watershed are important to the integrity of downstream waters: "Downstream waters are the time-integrated result of all waters contributing to them" (EPA 2015:ES-5).

The EPA report included several case studies and supporting research that focused on the Little Colorado subregional watershed and the Gila River system (which is downstream of the Salt watershed). For example, Shaw and Cooper (2008) focused their research on the relationships between the physical

[2] This is commonly known as the "Rapanos" ruling, which explored what type of water features are considered regulated "waters of the U.S." under the Clean Water Act (EPA and U.S. Army Corps of Engineers 2008). The EPA undertook its 2015 review to bridge the gap between the legal terminology of "significant nexus" and the scientific understanding of watershed systems.

characteristics of watersheds, stream reaches, and riparian plant communities for 14 ephemeral stream reaches tributary to the Little Colorado River. They found that stream-reach characteristics are influenced by and connected to distant portions of the contributing watershed.

Little Colorado Watershed – Direct Benefits Pathway

The Little Colorado River is a major tributary to the Colorado River, entering the Colorado River system just below Marble Canyon at the Grand Canyon National Park boundary (river mile 627). The headwaters of the Little Colorado arise in the White Mountains of eastern Arizona before flowing northward through the high grasslands and desert of the Colorado Plateau. The implementation of the WMAT IFM carbon projects directly impacts and benefits the Little Colorado River, which delivers, on average, approximately 275,000 acre-feet of surface water into the Colorado River system annually.[3]

The major diversions of flows from the lower Colorado River for California users occur downstream of the river's confluence with the Little Colorado River near the eastern portion of the Grand Canyon. The Whitsett Intake Plant, located on the west side of Lake Havasu upstream (north) of Parker Dam, is the intake point for the Colorado River aqueduct, one of the primary diversion points of Colorado River water into California (river mile 194). Other main diversions of Colorado River water into California are farther downstream and include the Palo Verde Canal at Palo Verde Dam (river mile 134) and the All-American Canal at Imperial Dam (river mile 49). Therefore, benefits to the Little Colorado watershed bestow benefits to the Colorado River, which in turn bestows benefits to California water users.

Salt Watershed – Direct Benefits Pathway

The streams and rivers in the Salt watershed supply water to the Salt River, which is the largest tributary to the Gila River. The Gila River flows into Arizona from its headwaters in New Mexico, with several of its major tributaries arising from the forests of the central highlands below the Mogollon Rim. Major tributaries include the Salt River, along with the San Francisco River, White River, and Black River. Downstream of the confluence of the Salt River with the Gila River southeast of Phoenix, Arizona, the Gila River largely flows through low desert alluvial valleys and eventually enters the Colorado River between the Imperial Dam and the city of Yuma.

The Salt and Gila River contributions to the Colorado River are especially pronounced during years with higher-than-normal flows, when the Gila River often becomes the dominant contributing feature of the Lower Colorado region. In fact, the Gila River can rapidly approach or exceed the flow of the Colorado River during and following large flood events. For example, during the historic 1993 winter floods, the flow of the Gila River remained historically high for the period from January through July, and flow in the Gila River even exceeded flow in the Colorado River for a sustained period of 5 months from February through June.[4]

The location of the Gila River's confluence with the Colorado River system and the Gila River's flow contributions result in unique beneficial ecological impacts. Downstream of Yuma, the Colorado River enters the Colorado River delta region, a rich and biodiverse area that has been named a Biosphere Nature reserve by the United Nations. The delta region has changed greatly since the construction and operation of the Imperial Dam, and the importance of ensuring that enough water enters the delta to maintain and enhance the local biological resources has been internationally recognized. The waters in the river and its

[3] Based on USGS gage 09402300, period of record 2004–2021.

[4] Based on USGS gages 09520500 and 09521100, period of record 1963–2021. "Historically high" refers to the fact that flows between January and July 1993 were higher than 95% of the flows recorded over the entire period of record.

delta support habitat for terrestrial, aquatic, and avian threatened and endangered species, including the desert pupfish and Yuma rail. The delta is particularly important to migratory birds, forming part of a migratory pathway that extends northward through the Central Valley of California. A recent study estimates that 17 million birds pass through the Colorado River delta region during spring migration, and more than 14 million during fall migration (DeLuca et al. 2021).

Maintaining flows to the Colorado River delta to preserve its unique biological integrity, along with downstream water quality, has been recognized as a priority for the United States and Mexico, especially in recent years. In 2019, Colorado River water users (including California) and Mexico signed Minute 323, the latest agreement to deliver flows downstream to the Gulf of California (United States and Mexico International Boundary and Water Commission [IBWC] 2017, 2019). Additionally, Minute 319 (agreed to in 2012 and since expired) allowed for a historic one-time pulse of released water downstream from the Morelos Dam south of Yuma in spring 2014 (IBWC 2012). That pulse connected the Colorado River to the Gulf of California for the first time in 16 years and resulted in increased vegetation in the floodplain and higher populations of migratory and nesting birds (IBWC 2014, Wiles 2014). Minute 323 now includes a focus on salinity control, environmental flows through the delta region, and conservation projects in Mexico (IBWC 2017, 2019).

Relationship between Salt and Little Colorado Watersheds – Additional Benefits Pathway

WMAT's actively managed forest carbon projects span two watersheds that feed the Colorado River: the Salt watershed (via the downstream Gila watershed) and the Little Colorado watershed. These watersheds are adjacent and are closely linked through ecosystem health and wildfire behavior. Because of this link, the benefits of protecting from wildfires and improving forest resiliency in either of the watersheds greatly benefits both watersheds.

A specific example of this link is how fire propagates from the Salt watershed into the Little Colorado watershed. Due to the unique topography of Arizona, the important forest treatment areas in the Salt watershed extend well beyond the boundaries of the 210,000 acres improved under WMAT's two carbon projects and protect the Little Colorado watershed, as well. One of the unique features of Arizona is the topographic feature known as the Mogollon Rim. The Mogollon Rim is a geological escarpment that extends from New Mexico to northwestern Arizona. Formed at the southern edge of the Colorado Plateau, the Mogollon Rim separates the central highlands of Arizona to the south (with elevations around 4,000 to 5,000 feet above mean sea level) from the high mountains and plateau regions to the north (which range from 6,000 to 8,000 feet). Not only does the rim form an abrupt and striking elevation change, but in many places, the rim also represents the approximate separation between the Salt watershed (flowing generally southwest) and the Little Colorado watershed (flowing generally northwest).

This change in elevation between the two watersheds has a critical effect with respect to wildfires. Wildfires tend to follow topography upward in elevation; therefore, major wildfires that start in the headwaters of the Salt watershed tend to move upward and into the higher-elevation Little Colorado watershed. This was the case for the two largest wildfires in Arizona history:

- The Wallow Fire was the largest wildfire in Arizona state history, burning over 538,000 acres in 2011. The fire started on May 29 southwest of Hannagan Meadow from an improperly extinguished campfire in the Bear Wallow Wilderness. This area of the Apache-Sitgreaves National Forests drains to the Black River, which ultimately joins with the White River to become the Salt River, the largest tributary to the Gila River. By June 7, the Wallow fire had moved northeastward and higher in elevation, crossing the boundary into the Little Colorado watershed. The fire burned directly along the Little Colorado River itself near Greer, Arizona, before being contained roughly a week later. Some of the areas of the highest-intensity burn occurred in the Little Colorado watershed. In the end, 130 miles of the Little Colorado River were impacted directly or indirectly by the Wallow Fire (U.S. Forest Service and Arizona Game and Fish Department 2011).

- The Rodeo-Chediski Fire was the second largest wildfire in Arizona state history, burning over 468,000 acres in 2002. The initial Rodeo fire started on June 18 from arson on the White Mountain Apache reservation near Cibecue, in an area draining south to the White River. The initial Chediski fire started on June 20 (accidental), on the Apache-Sitgreaves National Forests in an area draining south to the Salt River. In less than 2 days, the combined fire complex had moved upward and crossed the Mogollon Rim, entering the Little Colorado watershed. The Rodeo-Chediski Fire continued to burn for several more weeks within the Little Colorado watershed.

Preventing catastrophic wildfires in the Salt watershed directly prevents catastrophic wildfire in the Little Colorado watershed due to the adjacency of the two watersheds, the unique topography that forms the boundary between the two watersheds, and the predominant winds, which come from the southwest. The WMAT IFM projects reduce the risk of severe wildland fires through their use of active fire and fuels management in both the Salt and the Little Colorado watersheds. This has a direct benefit on the water quality in the local headwaters and all downstream connected waters.

DIRECT ENVIRONMENTAL BENEFITS TO CALIFORNIA WATERS

Water Quantity

Water quantity as a function of a forest ecosystem health can be attributed to proper forest management, including sustainable yield harvesting and catastrophic wildfire prevention. The management practices and activities employed under the projects (e.g., prescribed fires, timber harvesting, thinning, pest management) are detailed in WMAT's Wildland Fire Management Plan (BIA Fort Apache Agency 2015) and certified Forest Management Plan (Williams et al. 2005).

Proper management of a forest ecosystem where forest activities and prescriptions contribute to both ecological and wildfire resilience leads to a system where water quantity is spread throughout the water year. In the mountainous areas of Arizona, watersheds that are properly managed store snowpack later into the season, resulting in sustained runoff during the summer and more water available for downstream users. This is especially important when looking at the impacts of climate change. Proper watershed management provides resilience against future climate change and reduces the potential for negative outcomes. Proper forest management, such as the practices included in the WMAT IFM carbon projects, is important for preserving water quality and quantity for downstream users now more than ever because of the increased risk of catastrophic wildfire, prolonged drought, and so forth, from climate change.

Sustainable yield harvesting is a forest management technique that leaves a desirable mix of tree species and ages that can be maintained and developed for long-term forestry health (Williams et al. 2005). WMAT's FMP includes timber harvesting standards for maintaining a healthy forest composition and minimizing damages to natural resources during harvesting activities, which allows for more sustainable growth of desirable tree species, increased soil stability, cleaner and steadier water flows, and ecological resilience (Williams et al. 2005). The fire fuel management and strategic harvesting activities included in WMAT's carbon projects reduce the risk for wildland fires within the project areas and beyond. As noted above, fires tend to follow topography upward in elevation, so a fire that starts south of the rim may climb elevations and impact areas within both the Salt watershed and the higher-elevation Little Colorado watershed. Therefore, prevention and severity reduction of wildland fires through implementation of WMAT's projects benefit not only the local watershed, but also adjacent watersheds and their downstream waters.

Recent research in Arizona has highlighted the importance of properly managing forest ecosystems through restoration to maximize snowpack. Researchers examined regional-scale temporal trends in snow distribution across central and northern Arizona by studying satellite images. This research found that the snowpack at treated sites (i.e., sites similar to the WMAT IFM carbon project area) appeared to persist longer into the spring season, with potentially greater contributions to groundwater recharge in this semi-arid region (Sankey et al. 2015). Greater recharge to the groundwater systems results in increased baseflow downstream (Brooks 2012).

Generally, baseflow decreases and surface water runoff increases following severe wildland fires in the semi-arid West. The surface water flow increases that result from severe wildland fires or other stand-replacing events are typically short term (peaking in the first couple years) and approach pre-fire levels once vegetation returns. Although the increased surface water flow is short term, the runoff water is less available for use by riparian systems, compared with baseflows, and causes a combination of other issues, such as decreased water quality (e.g., increased sediment and nutrients in the surface water) and increased erosion (e.g., channel incision) (Neary et al. 2005). Deeply incised channels contribute more to the "draining" of the surrounding landscape since they pull more water from the surrounding landscape. Thus, forest management like that employed in the WMAT carbon projects is essential to securing water quality and quantity both within the region as well as for downstream ecosystems or users.

When catastrophic wildland fire and/or improper harvesting practices destroy large areas of vegetation, accumulated leaf litter, and other organic matter on the forest floor, significant impacts may occur to a number of interrelated hydrologic cycle functions, including vegetative interception of rainfall, soil infiltration rates, overland flow (i.e., runoff) of precipitation, baseflows, evapotranspiration rates, and soil moisture storage. Wildland fire and improper harvesting lead to the following direct negative effects on the hydrologic cycle and downstream water deliveries:

- **Interception is reduced**: Interception of rainfall by vegetation is reduced, which allows for greater throughfall of raindrops to the soil surface. Increased throughfall can lead to compaction of the soil surface, which reduces infiltration.
- **Infiltration capacity is reduced:** Soil infiltration capacity (i.e., the maximum infiltration rate) following storm events and snow melts is reduced.
    - Typically, infiltrated water flows slowly downgradient to the nearest stream channel or percolates to the groundwater aquifer. When more rain falls than can infiltrate the soil, it runs off the surface.
    - Following a wildfire, organic matter and associated earthworm, insect, and burrowing animal activities on the forest floor are reduced, which decreases soil porosity and infiltration.
    - When burning causes exposure of bare soil from loss of organic matter, the soil structure can collapse and lead to an increase in the bulk density of the soil, which reduces infiltration.
    - Compaction and displacement of bare soil and buildup of ash and charcoal reduce infiltration.

    - Increased water repellency as a result of extreme heating and the distillation of organic compounds in the litter layer onto the soil surface layer (Neary et al. 2005), causing an impermeable layer and thus reducing infiltration.
  - The relationship between precipitation rate and infiltration rate is especially important in the arid West. Baseflow decreases and runoff increases, along with the effects of this, are exacerbated in the arid West, where precipitation from summer storms often occurs through high-intensity, short-duration rainfall bursts.
    - The decreased infiltration and increased runoff result in increases in downstream water quantity. However, those increases are short term, and the flows have not benefited from the filtration of contaminants through the infiltration process.
- **Runoff/overland flow is increased:** Reduced infiltration leads to a greater quantity and velocity of overland flows. The risk of flash floods and flood levels increases.
  - Accelerated overland flow increases erosion, soil loss, and sedimentation in the local watershed and downstream waters. Erosion is often the second most visible effect of wildland fire.
  - Ash and charcoal buildup can be carried downstream more readily with accelerated overland flows.
- **Baseflows are reduced**: The reduction in infiltration leads to reduced baseflows, which reduces flow contributions to perennial and intermittent streams between storm events and snow melts. Alternatively, less evapotranspiration can lead to increased baseflows.
- **Evapotranspiration is reduced**: Until vegetative cover returns, the reduced evapotranspiration leaves more water in the soil after the growing season and causes the soil to be less able to absorb rainfall from storm events (i.e., infiltration capacity is reduced).
  - Loss of vegetation lowers evapotranspiration.
  - Increased evapotranspiration increases runoff and peak streamflow rates.
  - In snowy areas, large fires decrease snowpack and small fires increase snowpack. The snowmelt, evaporation, and sublimation rates are increased after wildfires.
- **Soil moisture storage is affected:** Wildfire can cause soil moisture storage to increase in some instances and decrease in others, but either way, these instances negatively impact downstream water deliveries.
  - At the beginning of the growing season, soil is typically charged to field capacity (i.e., maximum storage) as a result of snowpack accumulation and subsequent melting. However, wildfires have the potential to decrease snowpack, thus reducing the water availability for vegetation and groundwater recharge. When ecosystems are properly managed, vegetation uses the stored water from snowpack and infiltration during the growing season; evapotranspiration also consumes some stored water. Precipitation events at the end of the growing season replenish the water storage in the soil.
  - The reduction in evapotranspiration and infiltration leads to higher runoff but can have varying influence on soil water storage.
    - Lower evapotranspiration leads to lower losses to the hydrologic cycle and leaves more water in the soil. Subsequent precipitation events are then more likely to lead to runoff.

        - Lower infiltration reduces soil moisture storage and leads to greater overland flows (Neary et al. 2005).
    - Leaf litter storage of water is decreased or eliminated, depending on the severity of the fire.

These effects are more pronounced with high-severity fires and less pronounced with small fires such as prescribed fires. Severe, stand-replacing wildfires generally lead to a net increase in runoff in the near term due to the various impacts on the hydrologic cycle. This increased runoff is often in the form of destructive peak flows that cause erosion, soil loss, and sedimentation in downstream waters. Additionally, these overland flows after a wildfire typically carry ash and charcoal, which reduces water quality downstream. Through the use of controlled, smaller prescribed burns and reduced wildfire risk (which is the result of forest management within the two WMAT IFM carbon projects), beneficial baseflows are improved and destructive peak flows are reduced. Proper forest management and wildfire prevention can increase the water quantity available through downstream baseflows and decrease destructively high runoff (Neary et al. 2005).

Hallema et al. (2018) analyzed wildland fire, climate, and river flow records for 168 watershed regions across the contiguous United States between 1980 and 2016 in an attempt to identify trends in impacts from burned forests on water supplies. The results of the study showed that changes in post-fire river flows were highly variable between different regions and climates and could be attributed to both wildland fire effects and interannual climate variability (e.g., drought conditions). The Fort Apache Indian Reservation and WMAT IFM carbon projects are located in the semi-arid Lower Colorado region (HUC 15), which encompasses the majority of Arizona. The analysis of this region showed that the post-fire 5-year mean annual river flow increased by approximately 26% despite an approximately 6% decline in precipitation (Hallema et al. 2018), thus highlighting the outsized importance of the improved forest management of the WMAT carbon projects.

Sun et al. (2019) built on the Hallema et al. (2018) study and other previous related studies. The Sun et al. (2019) study used existing data on wildland fire characteristics, climate, river flow, topography, and land cover to model local wildland fire–climate–environment interactions to identify the impact of wildland fire on annual river flow. The data were also used to estimate the potential fire risk to water supplies. This study showed that regions with more common use of low-severity prescribed fires had lower burned area ratios (BARs), compared with the smaller headwater catchments, such as the Lower Colorado region.

Both the Hallema et al. (2018) and Sun et al. (2019) studies showed that fires (prescribed or wildland) that affect more than 19% of a region have a notable effect on river flow. Although the Lower Colorado region had a reported median BAR of 15.4%, the BAR was greater than 39% in four Arizona rivers in the region (i.e., Sabino Creek, 87.2%; Wet Bottom Creek, 84.2%; Sycamore Creek, 39.5%; and Cave Creek, 75.5%). Fire impacts in Arizona were highest (e.g., greater than 100% increase in river flows) where more than one-half of the watershed area was burned (Hallema et al. 2018; Sun et al. 2019). Projects such as the WMAT IFM carbon projects reduce the risk and frequency of wildland fires, which can affect well over 19% of a region. This provides protection against destructive high-intensity peak flows.

Goeking and Tarboton (2020) reviewed a series of studies conducted between 2000 and 2019 and concluded that severe, stand-replacing fires in the semi-arid Southwest resulted in short-term increases in water yield. However, these increases were temporary and unfiltered. Moreover, the water yields actually tended to decrease overall in post-fire areas where there was high radiation (e.g., low elevations and south-facing slopes), rapid regrowth of vegetation (specifically with leaf-dense shrubs), and less severe disturbances (e.g., wildfire events that left most of the overstory trees alive) (Goeking and Tarboton 2020).

Water Quality

The quality of water can be significantly impacted by disturbances at the headwaters. Large burned areas contribute suspended and dissolved contaminants to downstream waters, which reduces water quality for wildlife and local ecosystems, in addition to complicating water treatment processes for human consumption and other uses downstream. When source-water quality is affected, treatment for human uses can be difficult because treatment systems are often set up to filter specific contaminants at anticipated levels. These impacts can last years following a wildland fire event (Neary et al. 2005; Sun et al. 2019; USGS 2012).

In healthy forests, like those managed under the WMAT IFM carbon protocols, water from precipitation and snowmelt is filtered through soils during infiltration. When precipitation runs off the soil surface and into a stream channel before being able to infiltrate the soil, sediment and other contaminants on the surface are more easily picked up and carried along than when the water has the chance to infiltrate into the baseflow after filtering through the surface layer(s) of soil. Forests that are improperly or poorly managed are not only at higher risk for severe wildfire, but can also use up soil moisture storage that would otherwise travel downstream as baseflow (Brooks et al. 2012; DeBano et al. 1998).

Depending on the size, location, and severity of the wildland fire, impacts to water quality vary in contaminant composition, concentration, and longevity. Severe wildfire causes a buildup of ash and charcoal from burnt vegetation and organic matter on the forest floor. This buildup is compounded by the formation of a water-repellent layer. Together, these increase surface runoff and sedimentation and allow contaminants introduced from fire-suppression efforts (e.g., fire-retardant chemicals that contain inorganic salts, thickeners, corrosion inhibitors, and bactericides) and combusted organic matter to be carried downstream. Rainfall events, especially high-intensity events, push the ash, debris, and other contaminants into streams, where it can be carried long distances. Some contaminants may also percolate into the soil, to be carried downstream with the baseflow. Common impacts to water quality following a fire include increased turbidity and total suspended solids (e.g., from disturbed soils and ash buildup); higher levels of total dissolved solids, dissolved organic carbon, nitrate, sulfate, nutrients, chloride, and iron; increased pH and alkalinity; and changes in color, taste, and odor characteristics (Sham et al. 2013).

Poor management of forest watersheds has the potential for natural disturbances to result in significant changes to the watershed processes. Wildland fire is the biggest risk to the natural hydrologic process. Forest watersheds that have been left untreated over the past 100 years are at a significantly higher risk of loss than watersheds that have been treated through the removal of biomass by mechanical methods or through prescribed burning (Stephens et al. 2012). Proper forest management and wildland fire prevention like that implemented in the WMAT forest carbon projects both preserve and improve water quality.

CONCLUSIONS

As demonstrated in this report, the health and management of forests in WMAT's two carbon projects are directly linked to watershed health and improved waters for downstream users, including the State of California, thereby complying with section 95989(b) of the Cap-and-Trade regulation. The two WMAT IFM carbon projects are providing DEBS to the waters of California by 1) protecting water quantity by promoting stable and consistent baseflow over flashy, destructive, or non-existent peak flows, and 2) reducing pollutants that could have an adverse impact on the waters of the State and thereby improving water quality.

Scientific literature supports the connectivity of headwaters to downstream watersheds through physical, biological, and chemical connections and describes the adverse effects that occur following wildfires.

There are well-established, direct links between healthy forest management practices—like those conducted within both WMAT carbon projects—and the health of the local and downstream watersheds. The WMAT IFM carbon projects span a total of 210,000 acres across both the Little Colorado and Salt subregional watersheds. The Salt and Little Colorado watersheds are both major tributaries to the Colorado River, which provides more than one-half of the water supply for southern California. Thus, by improving the health and resiliency of the forests that form the headwaters of both the Salt and Little Colorado watersheds, the health and resiliency of downstream water deliveries to California via the Colorado River are also improved.

The WMAT IFM carbon projects improve forest health through sustainable yield harvesting and reduce the risk of severe wildland fires through their use of active fire and fuels management in both the Salt and the Little Colorado watersheds. These practices have a direct benefit on the water quantity and quality in the local headwaters and all downstream connected waters, including the Colorado River. The two largest wildfires in Arizona state history—the Rodeo-Chediski and Wallow Fires—started in areas near and ecologically similar to the WMAT carbon project areas (but that had not been subject to IFM) and eventually affected both the Salt and Little Colorado watersheds. Management within the carbon project areas themselves has specifically targeted forest health and resiliency, and there has not been catastrophic fire within the forests managed under these two IFM carbon projects since the projects enrolled in the California compliance offset market.

The benefits to water quantity and quality of the Colorado River are in addition to the greenhouse gas reductions for which these IFM projects are receiving credits. Therefore, the WMAT IFM carbon projects meet the requirements of Section 95989(b) of the Cap-and-Trade Regulation and should be awarded Direct Environmental Benefits of the State status.

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