SUBMIT OPTION SUBMITTAL FORM BY:
1. EMAIL TO: COLORADORIVERBASINSTUDY@USBR.GOV
2. U.S. MAIL TO: BUREAU OF RECLAMATION, ATTENTION MS. PAM ADAMS, LC-2721, P.O. BOX 61470, BOULDER CITY, NV 89006-1470
3. FACSIMILE TO: 702-293-8418

Option Submittal Form

Contact Information (optional): ☐ **Keep my contact information private.**

Contact Name: Title: Research Scientist / Director CU-NOAA

Affiliation:

Address:

Telephone: E-mail Address:

Date Option Submitted: February 1, 2012

Option Name:

Dust Abatement for Colorado River Flow Recovery

Description of Option:

Desert dust is a strong forcing of earlier snowmelt and loss of flow in the Upper Colorado River Basin through its enhancement of absorption of solar radiation (Painter *et al.*, 2010). Present levels of dust loading are markedly greater than existed prior to the 1800s due to land surface disturbances of desert lowlands in the Colorado Plateau and Great Basin (Neff *et al.*, 2008), darkening the snow surface and accelerating snowmelt. The accelerated melt associated with this dramatic increase in dust deposition has affected the basin hydrograph and ultimately decreased yield by increasing sublimation rates, increasing evapotranspiration, and decreasing soil moisture. Modeling suggests that the dust forcing has reduced flow an average of 5% (0.8 MAF) and up to 7% in each year, shortened snow cover duration by ~ 3 weeks, and brought peak flow 3 weeks earlier at Lee's Ferry.

This option proposes mitigation of land use activities that disturb soil surfaces and restoration of disturbed sites with mechanisms to reduce soil mobility. Such mechanisms to keep Colorado Plateau and Great Basin soils in place would prevent or diminish dust loading in UCRB snowpacks. The potential to reduce dust loading through surface stabilization in the deserts and restore more persistent snow cover, slow runoff rates, and increase water resources in the UCRB may present an important mitigation opportunity to reduce system management tensions and regional impacts of climate change.

Location: Describe location(s) where option could be implemented and other areas that the option would affect, if applicable. Attach a map, if applicable.

Dust loading in the UCRB comes from the disturbed soils in the Colorado Plateau and the Great Basin, which are then deposited on UCRB snow cover. Dust is produced from both point sources, such as abandoned agricultural fields, and diffuse sources such as grazing lands. Areas vulnerable to dust production can be mapped by documenting soil loss before and after surface disturbance. Focal areas could then be chosen for restoration (point sources) and altered management regimes (diffuse sources).

Deposition in the eastern half of the UCRB (Colorado Rockies) comes primarily from sources

in the Four Corners region of the Colorado Plateau with point and diffuse contributions from all of the adjoining states. Deposition in the western half of the UCRB (Uintah Mountains, Wasatch Mountains backside, Wind River Range) comes primarily from point and diffuse sources in the Colorado Plateau and the Great Basin.

Runoff would increase throughout the Upper Basin due to dust abatement.

Quantity and Timing: Roughly quantify the range of the potential amount of water that the option could provide over the next 50 years and in what timeframe that amount could be available. If option could be implemented in phases, include quantity estimates associated with each phase. If known, specify any important seasonal (e.g., more water could be available in winter) and/or frequency (e.g., more water could likely be available during above-average hydrologic years) considerations. If known, describe any key assumptions made in order to quantify the potential amount.

Our modeling suggests that complete mitigation of elevated dust load since mid 1800s could restore an average 5% (0.8 MAF) and up to 7% of annual flow. Additional benefits include greater duration of the mountain snowpack reservoir, reduced runoff rates, and a delay in the naturalized flow peak at Lee's Ferry of an average of 21 days.

Climate warming has been projected to increase the frequency and severity of drought, to increase interannual precipitation variability, and to increase the areal expanse of desert regions. These responses are likely to increase the frequency and magnitude of dust emission from the Colorado Plateau and Great Basin under continued levels of soil disturbance (Seager *et al*., 2007; Belnap *et al*., 2009; Munson *et al*., 2011). It is likely that the impacts of a warming climate on snow accumulation, snowmelt, and CRB water yield will be strongly amplified by increased dust emission and deposition on mountain snowpacks.

Ongoing research indicates that enhanced dust deposition (akin to levels observed in 2009 and 2010) reduces annual flow by an additional 1%, and shifts runoff peak and centroid earlier by an additional 18 days. When combined with regional warming impacts on snow accumulation and melt, enhanced dust levels will likely induce further flow reductions of 10-20% and 18 - 30 days earlier flow.

However, complete mitigation of the increase in dust load since the 1800s seems unlikely. Therefore we propose a modeling scenario of a range of 3-5% restored flow from focused land partnership and management efforts:

A relationship between annual flow volume and the amount of increased flow should be developed based on the results of Painter et al. (2010), with larger increased flows occurring in higher runoff years. Peak flow would come 2 weeks later, the snowmelt season would be extended, and the mountain snowpack reservoir would remain intact 2 weeks longer.

Additional Information

Technical Feasibility: Describe the maturity and feasibility of the concept/technology being proposed, and what research and/or technological development might first be needed.

Stabilization of acute point sources, such as abandoned agricultural fields or even extensive areas with little to no vegetation, is highly feasible, as has been demonstrated at sites in China over the past 30 years. Straw is spiked into the soil in 2 x 2 m squares to create windbreaks at the soil surface. In regions of rainfall above ~200 mm, cyanobacteria are cultured and sprayed onto the site. Seeds and seedlings of vascular plants are then used to increase soil surface protection. Below that level of precipitation (a low percentage of Colorado Plateau lands), cyanobacteria are applied. However, establishment of plants is difficult without watering. In such areas, the Chinese have either only used the cyanobacteria or have developed dripline systems with solar-powered pumps to stabilize many square miles of sand dunes.

Reducing dust from diffuse sources will only be feasible through altered management regimes. By identifying the conditions under which dust is produced (that is, what combination of soil, vegetation, climate and disturbance), it will then be necessary to reduce disturbance of the soil surface in those places and at those times. As we already know that drought years are the most likely to be high dust years, we can reduce the impact on land users by targeting those times and specific soil types for restriction of use. The BLM already has a policy to limit grazing during drought. However, it is seldom enforced to the degree necessary for dust control.

Future actions should include:

1. Identify major point and diffuse dust sources on the Colorado Plateau
2. Measure dust production at these sites through time to understand influence of climate, soil, plants, and disturbance
3. Expand mapping of vulnerable soils
4. Reduce dust production from point sources through rehabilitation efforts
5. Reduce dust production from diffuse sources through altered land use regimes (e.g., timing and intensity of use)
6. Monitor dust production with remote sensing tools and an expanded dust collection network
7. Monitor snowpack dust impacts and response with remote sensing tools and an expanded energy balance measurement network

Further study will enhance restoration efforts and enable an adaptive management and restoration strategy. Major point dust sources on the Colorado Plateau can be identified and mapped by remote sensing at a regional and landscape scale, and their dust emissions tracked over time. Remote sensing is not able to detect more diffuse sources. For these areas, dust production needs to be measured with a network of dust collectors before and after disturbance on and in different soil and vegetation types to determine vulnerability.

An Upper Basin focal area could be further refined or pinpointed following a characterization and mapping of the dominant soil units contributing to dust storms, and determining the susceptibility of each unit to wind erosion before and after disturbance of the soil surface. Future study needs should include the following actions: "monitor and measure dust at chronic and acute dust sources, expand mapping of vulnerable soils, and suggest ways to reduce dust production."

On the snowpack side, monitoring of snow covered area, snow albedo, and dust radiative forcing in snow from airborne and spaceborne remote sensing (e.g. the new Jet Propulsion Laboratory Airborne Snow Observatory, MODIS snow property retrievals) and in situ energy balance and radiation towers (JPL/WWA Western Energy Balance of Snow network) will determine the efficacy of dust mitigation efforts. With point snowmelt modeling at existing and future energy balance and radiation towers (as per Painter *et al* 2007), we can determine the deceleration of snowmelt due to reduced dust loading from mitigation.

Costs: Provide cost and funding information, if available, including capital, operations, maintenance, repair, replacement, and any other costs and sources of funds (e.g., public, private, or both public and private). Identify what is and is not included in the provided cost numbers and provide references used for cost justification. Methodologies for calculating unit costs (e.g., $/acre-foot or $/million gallons) vary widely; therefore, do not provide unit costs without also providing the assumed capital and annual costs for the option, and the methodology used to calculate unit costs.

Dust abatement costs are uncertain. The Chinese have pursued dust abatement in arid areas and there are likely lessons on costs, successes, and failures to be learned.

Permitting: List the permits and/or approvals required and status of any permits and/or approvals received.

Unknown

Legal / Public Policy Considerations: Describe legal/public policy considerations associated with the option. Describe any agreements necessary for implementation and any potential water rights issues, if known.

To the Upper Basin states, future earlier runoff timing due to both dust and climate change will create management challenges. The snowpack represents a critical storage reservoir in the Upper Basin, which does not have the regulatory control over flow enjoyed by the Lower Basin. Hence, dust abatement will mitigate some of the current and projected advances in runoff timing under anthropogenic warming. Additional flow amounts provided by dust abatement will create new water usable under by the Upper Basin under its compact rights. Alternatively, such flows could be delivered to the Lower Basin in order to reduce the risk of a compact 'call'.

In the Lower Basin states, the change in timing is largely mitigated by Lake Powell and Lake Mead, but the recovery of additional runoff has long-term implications. Until such time as the Upper Basin uses its full compact apportionment, these increased flows will provide Lower Basin users with additional flows.

Some of the necessary dust abatement will need to occur on the Navajo and Hopi reservations in Northern Arizona. This may impact some traditional land uses such as grazing and hence conflict with local values and economic production. Reductions in dust should have substantial health benefits, especially on the Navajo Reservation, even if presently unquantifiable.

Dust abatement has the potential to counteract some of the negative consequences on basin flow due to climate change and hence is a more general climate change adaptation strategy.

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Implementation Risk / Uncertainty: Describe any aspects of the option that involves risk or uncertainty related to implementing the option.

The quantification of additional flows due to dust abatement is somewhat uncertain and needs additional science.

Land restoration attempts coinciding with a large, persistent and lengthy drought may prove fruitless.

Reliability: Describe the anticipated reliability of the option and any known risks to supply or demand, such as: drought risk, water contamination risk, risk of infrastructure failure, etc.

The connection between dust abatement on runoff timing is robust. The annual amount of additional runoff will vary from year to year, with more flows generated in higher years.

Water Quality: Identify key water quality implications (salinity and other constituents) associated with the option in all of the locations the option may affect.

Water quality degradation due to wind and water deposited sediment (and the salinity and selenium contained within) can be mitigated by reducing soil surface disturbance and restoring already degraded landscapes. Enhanced snowmelt runoff under high dust loading can also lead to increased stream erosion with commensurate elevated turbidity and dissolved load. Hence reduction of dust should improve water quality.

Energy Needs: Describe, and quantify if known, the energy needs associated with the option. Include any energy required to obtain, treat, and deliver the water to the defined location at the defined quality.

Energy Required	Source(s) of Energy
None	

Hydroelectric Energy Generation: Describe, and quantify if known, any anticipated increases or decreases in hydroelectric energy generation as a result of the option.

Location of Generation	Impact to Generation
Basinwide	Increases in both annual energy production (more water), and instantaneous power production (higher head).

Recreation: Describe any anticipated positive or negative effects on recreation.

Location(s)	Anticipate Benefits or Impacts
Upper Basin	Longer Rafting Season
Upper Basin	Longer Skiing Season
Upper Basin	Perhaps Longer Fishing Season

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Environment: Describe any anticipated positive or negative effects on ecosystems within or outside of the Colorado River Basin.

Location(s)	Anticipated Benefits or Impacts
Upper Basin	Reduction of increases in runoff timing associated with anthropogenic warming
Upper Basin	Cooler stream temperatures late in the year when runoff is low due to higher low flows.

Socioeconomics: Describe anticipated positive or negative socioeconomic (social and economic factors) effects.

The value of the produced water will be significant.

Some of the necessary dust abatement will need to occur on the Navajo and Hopi reservations in Northern Arizona. This may impact some traditional land uses such as grazing and hence conflict with local values and economic production. Reductions in dust should have substantial health benefits, especially on the Navajo Reservation, even if presently unquantifiable.

Other Information: Provide other information as appropriate, including potential secondary benefits or considerations. Attach supporting documentation or references, if applicable.

The submitters are willing to work with Reclamation to devise the specifics to this proposal which can be modeled easily in CRSS. Other members of the submission team include Jayne Belnap of the USGS and Jeff Deems of the Western Water Assessment and the National Snow and Ice Data Center.