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Short and long-term analyses of plant greenness and evapotranspiration dynamics in the riparian zone of the Colorado River Delta before and after the 2014 Minute 319 environmental pulse flow

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Our study assessed the effects of ecological environmental flows from one nation to another, using remote sensing. Remote sensing approaches to plant water use quantification can inform binational, integrated water resources management. We provide plant water use estimates to plan for allocation of water in the Colorado River in USA and Mexico. Our study examined multi-year effects of a 2014 historically important binational experiment (the Minute 319 agreement of a water treaty between the U.S. and Mexico) on vegetative response along the riparian corridor for the years following the pulse flow which began in 2014. We divided our study area into seven reaches and used remotely sensed imagery to exam vegetation greenness and plant water use or evapotranspiration (ET, the loss of water through evaporation from the instruments, the 250 m Moderate Resolution Imaging Spectroradiometer (MODIS) and 30 m Landsat 8 OLI satellite imagery to track ET and several vegetation indices to estimate the greenness of vegetation (e.g., NDVI, scaled NDVI, EVI, EVI2). The Minute 319 environmental flow produced a 17% increase in VI ("Greenness") as detected with Landsat throughout the riparian corridor in 2014. The significant greening up was observed across reaches within the riparian zone, as well as in the non-inundated outer parts of the riparian floodplain, where groundwater supported existing vegetation. However, after just two years (by the end of 2016) there was a 22% decrease in VI throughout the riparian corridor. In 2017, an annual overall increase of 2% in greenness was calculated, before falling again, by 8%, over the year 2018. From 2015-2018, the initial post-pulse greenup and ET as measured by Landsat (30m) & MODIS (250m) steadily declined, falling below pre-pulse levels in all reaches. The VI response becomes bimodal and disintegrates after 2016 in all reaches except for in Reach 4, the restoration zone. Our longer time-series analysis from 2000-2019 showed an

overall increase in VIs (higher Greenness) and ET (more water loss) in the year of the 2014 pulse and in the year, 2015. The higher VI and ET indicate that there was enough water in the riparian zone to generate a positive response from plants. These results reversed a decline in VI and ET since the last major flood in 2000, but the effect did not last after the first couple of years after the pulse flow. Our longer-term data results from 2000 through 2019 (approximately the last 20 years), showed that Landsat EVI (Greenness) declined 34% and ET (mm/day) declined 38% and since the 2014 Pulse Flow through 2019, Landsat EVI (Greenness) declined 20% and ET (mm/day) declined 23%. The pulse flow in 2014 contributed enough water to slow the declines by almost two-thirds. Added in-stream water helped native and invasive riparian species in terms of stand structure, extent and greenness but only for the very short-term. Our results support the conclusion that the Minute 319 environmental flows from the U.S. to Mexico had a positive, but short-lived (one or two year), impact on vegetation growth in the delta.