YOLO BYPASS USFWS EASEMENTS
Impact Analysis from the Big Notch Project

Prepared for:

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Bureau of Reclamation

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1 INTRODUCTION

The Bureau of Reclamation (Reclamation), in partnership with the California Department of Water Resources (DWR), is implementing the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project (Project) to increase the availability of floodplain habitat for juvenile salmonids, as well as to reduce migratory delays and loss of fish at Fremont Weir and other structures in the Yolo Bypass. DWR is the lead agency for acquiring the requisite flowage easements to allow for operation of the Project starting in the Fall of 2023.

The U.S. Fish and Wildlife Service (USFWS) owns eight conservation easements on 17 individual parcels in the Yolo Bypass which will be affected by the Project (Figure A). The USFWS' conservation easements further the National Wildlife Refuge Systems' mission to administer a national network of lands and waters for the conservation, management and, where appropriate, restoration of the fish, wildlife and plant resources and their habitats within the United States for the benefit of present and future generations of Americans. These easements were obtained by USFWS from private landowners within the Yolo Bypass for the purpose of protecting migratory bird habitat and are administered as part of the National Wildlife Refuge System. Conservation easements are agreements between the landowner and USFWS that allow for the landowner to retain private ownership of a parcel while limiting the development of that parcel to agreed-upon conservation standards.

As proposed, operations of the Project will increase the frequency, depth, and duration of flooding on USFWS Conservation easements. To achieve operations of the Project, it will be necessary for DWR to acquire flowage easements on the parcels impacted by the Project. Per the USFWS Conservation Easement Document, owners must receive prior authorization from the USFWS before entering into third-party agreements that may impact the USFWS easement interests. USFWS is required per the Code of Federal Regulations (50 CFR 25.44) to complete a compatibility determination prior to issuing a permit authorizing DWR Flowage Easements. A compatibility determination is a written determination signed and dated by the refuge manager and Assistant Regional Director of Refuges, signifying that a proposed or existing use of a national wildlife refuge is or is not a compatible use.

It should be noted that while this study is funded by, and intended to evaluate impacts specific to USFWS easements, other conservation easements occur within the Yolo Bypass that were similarly developed for the purposes of providing wetland habitat.

1.1 BNP PROJECT

The purpose of the Project, also referred to as the Big Notch Project (BNP), is to enhance floodplain rearing habitat and fish passage in the Yolo Bypass and suitable areas of the lower Sacramento River. The Project's intention is to allow water to enter the Yolo Bypass region more frequently, and at lower river stages. Ideally, moving this additional water into the floodplains within the Yolo Bypass will provide juvenile salmon with high-quality habitat that will increase their survival chances as they migrate to the Pacific Ocean. The project constructed a headworks structure, an outlet channel, and downstream channel improvements. Each of these facilities are components of the three different channel alignments (east, center, and west) in the Yolo Bypass. Each alignment would terminate downstream into the existing Tule Pond.

The Project will allow increased flow from the Sacramento River to enter the Yolo Bypass through a gated opening (i.e., notch) on the east side of the Fremont Weir. The Fremont Weir at the location of the Project, has an approximate elevation of 32 feet North American Vertical Datum of 1988 (NAVD 88). The BNP has three gates to control water moving through the facility into the Yolo Bypass. The invert of the new lowest gate is at an elevation of 14 feet NAVD 88, which is approximately 18 feet below the crest of the existing Fremont Weir. The invert of the other two gates is an elevation of 18 feet NAVD 88. The Project will connect the new gated notch to Tule Pond with a channel that parallels the existing Yolo Bypass east levee. Gate operations could begin each year on November 1 dependent on river conditions. Gate operations to increase inundation could continue through March 15 of each year, based on hydrologic conditions. The Project will operate to allow flows through the Project's headworks structure up to 6,000 cubic feet per second (cfs). The gated notch is also expected to provide open channel flow for adult fish passage, juvenile emigration, and floodplain inundation. The Project includes a supplemental fish passage facility on the west side of the Fremont Weir that will operate following Fremont Weir overtopping events and downstream channel improvements to allow fish to passage.

1.2 OBJECTIVES

The objective of this analysis is to provide USFWS with data to make a determination if the operations of the Project are consistent with the terms, conditions and intent of the conservation easements established on lands within the Yolo Bypass. The intent for the USFWS easements is for wetland habitat to be managed and maintained in perpetuity. If landowners do not have the opportunity to benefit from these managed wetlands through recreation activities such as hunting, the incentive and cost to provide high quality habitat and food resources for waterfowl will likely diminish and potentially result in the loss of habitat and resources.

1.3 LIMITATIONS OF ANALYSIS

The hydraulic model developed by Cbec Eco Engineering used in this analysis utilizes a digital elevation model that was purposefully modified such that the wetland units and surrounding water control infrastructure are "plumbed to drain". Therefore, water control structures through containment berms that typically vary in size from 24-36 inches in diameter are represented in the model as 50-foot-wide trapezoidal breaches. In a few key locations, the model contains drainage canals and drain points that do not actually exist, which could impact predicted outcomes in both scenarios. Despite model calibration efforts, the simplified drainage network used in the model likely overestimated the speed at which water moves across the modeled landscape. Therefore, the duration of flooding experienced by wetlands units within the model is likely biased low (DWR 2017). Additionally, the model assumes initial conditions are dry, despite many wetland units and rice fields being flooded by October 2 when normal water conditions exist. Therefore, the model is likely missing approximately 25,000 acre-feet of water. Despite these limitations, Ducks

Unlimited (DU) expects that the number of flood events experienced by wetland units within the model was likely representative when compared to real-world conditions.

Another hydraulic model of the study area was developed by MBK Engineers. This model takes a different set of assumptions when considering the drain limited aspects of the Yolo Bypass and represents each wetland unit as a closed cell instead of the "plumbed to drain" approach. DU attempted to include this model in our analysis to create a more balanced approach by comparing both model outputs. Recognizing that one model represents an overestimate of drain speed within the Yolo Bypass and the other representing an under drained bypass, real world conditions are likely somewhere between the two different model approaches. A comparison would have provided additional insight into the importance that these different assumptions about drainage within the project area. However, DU was unable to gain permission to release critical data to MBK to effectively re-run their model to then compare the two model outputs.

Therefore, the analysis presented herein is derived solely from the hydraulic model developed by Cbec Eco Engineering. As with any model, a simplified landscape had to be used to facilitate model construction and allow for reasonable processing times which ultimately limits the ability of these model results to fully represent current conditions within the study area. These simplifications make extrapolating model results to predict future conditions at the wetland unit level with a high degree of accuracy challenging, yet within-model comparisons between different wetland units and water years provide insight as to which regions are most impacted by different scenarios. Specifically, DU examined how different water years and scenarios (baseline conditions, and the BNP implementation) produced different flood outcomes for individual wetlands units. While these different flood outcomes are not a perfect prediction of future conditions, the difference between scenarios or regions within the study area can provide insight into how future changes are likely going to impact flood duration, water surface elevation, and flood frequency. There is the possibility that model inaccuracies or errors exist due to landscape changes (such as the addition or removal of drain structures since the model's creation) which may influence the movement of water within the project area. These errors will reduce the accuracy of within model comparisons between wetland units and across scenarios. Therefore, DU advises that any conclusions drawn from this analysis be approached with caution and validated through alternative means or expert consultation.

The developers and distributors of this analysis disclaim any liability for damages or losses resulting from its use, and users are solely responsible for the interpretation and application of its findings.

1.3.1 Stressors

Several new stressors have the potential to affect the impacts from the BNP, including but not limited to: the Elkhorn slough restoration project, the Food for Fish program, the Egbert tract tidal restoration project, and several additional tidal restoration projects proposed in the southern portion of the bypass. These cumulative landscape changes, in addition to climate change and sea level rise, can dramatically modify how water flows through the focal area, ultimately impacting the metrics DU considered in our analysis. For example, modifications to areas that influence the

Sacramento River stage north of the Yolo Bypass could influence flood timing and duration. Similarly, modifications to areas south of the Yolo Bypass that modify the tidal prism and ultimately inflows to the Toe Drain, could influence drain speed within the Yolo Bypass, either reducing or increasing drain times. Climate change could result in increased surface water runoff during winter months instead of being captured as snowpack, which would increase BNP operational opportunity, resulting in greater flooding within the Bypass prior to March 15th.

1.4 IMPORTANCE OF YOLO BASIN TO WATERFOWL

Approximately 90% of California's Central Valley seasonal and floodplain wetlands have been destroyed or modified by agricultural conversion, development, and flood control efforts (Mitsch and Gosselink 2007; Frayer et al. 1989; Hanak et al. 2011). As a result, many wetlands dependent species have suffered population declines, including waterfowl – which have declined from 50 million historically to 6 million currently – and native freshwater and pelagic fish species (Mount 1995; Reid and Heitmeyer 1995; Sommer et al. 2007). Waterfowl populations are most abundant within the Central Valley in winter, and primarily rely on seasonal wetlands and flooded rice agriculture to access the food resources required to survive (CVJV 2020). The Yolo Basin contains approximately 11,500 acres of seasonal wetlands and up to 13,500 acres of winter flooded rice, which combined provide enough food resource to support approximately 3 million duck energy days between fall and spring. The 55 wetland units that form the basis of our analyses comprise approximately 35% of the seasonal wetlands present in the Yolo Basin and are expected to support over 330,000 duck energy days over winter.

1.5 IMPORTANCE OF HUNTING AND WETLAND MANGEMENT

The seasonal wetlands that support wintering waterfowl in California's Central Valley are shallowly flooded (approximately 12 inches deep to allow waterfowl to forage) from fall to early spring. These conditions rarely occur naturally in the highly modified landscape of California's Central Valley. Instead, these conditions are created through the efforts of private landowners and state and federal agencies. Generally, wetland management actions focus on the timing and depth of water, combined with mechanical disturbance to create conditions which produce the annual plant seeds and invertebrates that waterfowl favor (Fredrickson and Taylor 1982; Euliss and Harris 1987; Baldassarre and Bolen 2006). These management actions are expensive and time intensive. There are also additional costs associated with maintaining the water management infrastructure required for seasonal wetlands. Private land managers typically pay these annual costs to benefit waterfowl and waterfowl hunting; yet, these actions also benefit other wetland dependent wildlife species, including listed species such as the greater sandhill crane (*Antigone canadensis*), and giant garter snake (*Thamnophis gigas*) (Gilmer et al. 1982; Gildo et al. 2002; DiGaudio et al. 2015).

2 METHODS

DU used hydraulic model data produced by the TUFLOW classic model for the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Hydrodynamic Modeling effort to assess how the operation of the BNP could impact flooding on 55 wetland units within the Yolo Bypass. DU made no modifications or changes to the model architecture or data used to parameterize the model. DU used model outputs to evaluate daily changes in water surface elevation between October 2nd and March 15th across 16 water years (1996-2011) for each wetland unit. A water year is a 12-month period that begins on October 1 and ends on September 30. The water year is named after the calendar year it ends in. For example, the water year that ended on September 30, 2010 was the 2010 water year. Wetland unit-specific water surface elevations were assessed at a fixed point within each unit under two scenarios: baseline conditions and with the operation of the BNP. Each water surface elevation reference point was located near the drain within each wetland unit.

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To evaluate how changes in water depth within each wetland unit can impact wetland management actions, as well as landowner access and use of the units, DU defined three depth thresholds: six-inch water elevation increase, blind elevation, and berm elevation. (Figure B) These depth thresholds were applied to all wetland units, but specific values varied significantly over the entire study area due to topographic trends. Moreover, these thresholds account for a range of impacts, from small impacts at the six-inch increase threshold to large impacts at the berm elevation threshold.

The first depth category is intended to capture changes in water depth that would likely reduce or eliminate the ability of dabbling ducks to access food resources. DU assumed each wetland unit was managed at a target depth of approximately 12 inches at the start of each water year, as this is a favorable depth for most dabbling ducks to access food resources (Taft et al. 2002; Baldassarre and Bolen 2006; Baschuk et al. 2011). Therefore, an additional six inches of water would likely result in water depths that would preclude dabbling ducks from foraging and reduce the value of these areas to wintering waterfowl (Taft et al. 2002; Baschuk et al. 2011). DU added six inches to each unit's initial water surface elevation values to set the depth threshold for the first category.

The second depth category captures impacts to waterfowl hunting infrastructure. Hunters lose the ability to hunt pit blinds (blinds that are buried in the ground to provide hunters with concealment) when water overtops and fills the blind with water. Additionally, being able to access, and the effectiveness of stand-up blinds (blinds that sit at or above the water and are typically concealed with vegetation) are reduced when water levels exceed the floor of the blind. Therefore, DU measured all locatable blind elevations (top of pit blinds, floors of stand-up blinds) within each wetland unit, and averaged blind elevations to produce a unit-specific depth threshold for this category. There was a wide range of blind elevations largely driven by the variation in land elevations across the study site. However, the average blind elevation typically corresponded to an increase of 17 inches over the target water depth of a wetland unit.

The third depth category attempts to capture impacts to managed wetland infrastructure, including berm integrity and water control structures. These structures are critical to the management of the wetland and can be severely damaged or destroyed when submerged if water exceeds target depths. To determine the water depth that would correspond to these impacts DU used survey data collected between September 2023 and January 2024, to determine each wetland units' maximum exterior berm elevation. The survey datum is NAD 83 CA Zone 2, NAVD 88 Geoid 18 with the basis of elevations being OPUS Solutions. This approach provided us with a single elevation value that corresponds to the highest elevation observed on the exterior berm. DU chose to use the maximum elevation as it was the most conservative way to estimate berm overtopping. Similar to the range seen in average blind elevation, the maximum berm threshold elevation had significant variation; however, the average difference between pond bottom elevation and maximum berm elevation was found to be approximately 38 inches.

DU used these three depth categories in combination with the daily water surface elevation data to calculate three flood metrics for each wetland unit:

1. Duration – The total number of days that surface water elevation exceeded each threshold;
2. Flood Events – The total number of times surface water elevation exceed the corresponding threshold; and,
3. Hunting Impact Score – A weighted flood duration metric, where day values (based on hunter perceptions) are summed when water surface elevations exceed a defined threshold (six inch, blind, and berm) during a single water year.

DU calculated the total duration and the number of flood events at each depth category for each wetland unit using the R package *RmarineHeatWaves* (Smit et al. 2018). DU then summarized these data at the wetland unit level into the total number of flood events and the total duration of flood days at each depth category for all water years. DU also created a weighted flood duration score, termed hunt impact score, to better capture the overall impact of flooding events that occur during critically important periods for waterfowl hunters and landowners during a given water year. Day values were assigned to each day between Oct. 2 – Mar. 15 based on interviews with landowners, with factors such as waterfowl numbers, hunter success, and cultural importance being the primary factors considered (Figure C). Highly valued days received a larger score, with day scores ranging from one to five. DU found that waterfowl hunters within this study area favored opening weekend, and the months of December and January the most. DU also assigned day values to the days in October that precede the waterfowl hunting season. Although these days do not directly provide hunting opportunities, wetland water depth must be managed at target levels to establish waterfowl use within the area. Similarly, the periods between regular waterfowl season and the youth and veterans hunt weekends require wetland conditions to be maintained to continue to support waterfowl use and provide adequate hunting opportunities. DU applied the weighted day factor to the daily surface water elevation data, such that if a given depth threshold (six-inch, blind, berm) was exceeded, the corresponding day score was added to the water year total. The summed total of all day scores for each wetland unit, for each depth threshold was calculated for each water year. A maximum of 533 was possible, assuming a given depth threshold was exceeded for the entire water year. The resulting annual hunt impact scores provide insight into how different wetland units experience flooding during highly valued waterfowl hunting periods, and how different scenarios (baseline and BNP) influence the total hunt impact score for each depth threshold.

Peak BNP Impact Years

DU identified the water years that produced the largest difference between summed total impacts between scenarios to better understand the peak impacts attributable to the operation of the BNP. DU summed each flood metric (flood duration, hunt impact score, and flood event) by depth category across all wetland units for each water year in the baseline scenario, then subtracted these scores from the same totals produced under the BNP scenario to identify the four (or 25% of water years investigated) water years which resulted in the greatest flood metric increases attributable to the BNP (Table 1). This approach provided insight into how the operation of the BNP could transform moderate water years, which would typically produce zero or minimal impacts, into years that result in flood events. Moreover, water years that produced the largest overall impact scores never had the largest difference between scenarios (Table 1) due to both scenarios experiencing extensive flooding due to the complete overtopping of Fremont Weir.

The differences in impact scores across these top four most impactful water years were averaged at the wetland unit level to produce a single estimate of additional impacts attributed to the BNP during this subset of years. The averaged scores were then divided by the average impact score (across all 16 water years) under baseline conditions to determine the proportional increase (or decrease) in impact scores experienced by wetland units (Equation 1). This comparison between averaged “peak” impacts attributable to the BNP compared to baseline averages provides a benchmark to better understand which wetland units are most likely to experience the largest changes due to the BNP.

3 MODEL ANALYSIS RESULTS

DU examined daily water surface elevations for 55 managed wetland units (covering approximately 47,000 acres: 22,400 acres in the North Area, 19,600 acres in the Center Area, and 5,100 in the South Area) over a 16-year period, from October 2nd to March 15th (1996-2012). Of the 55 wetland units included in our assessment, 38 contained hunting blinds. DU assessed 158 blinds, of which, 47 were stand-up blinds and 111 were pit blinds. Our analysis relied on a single-point assessment of daily water surface elevation, which did not allow for an evaluation of how the flood footprint size would vary by years or between scenarios. Instead, our approach provided an approximate water surface elevation for each wetland in its entirety.

The water years that produced the greatest cumulative impacts under baseline conditions (1996,1997, and 2005) were rather consistent across the three impact classes and depth thresholds, suggesting that major flood events during major rainfall events impacted all impact metrics similarly (Table 1). These major flooding events likely coincided with Fremont Weir being overtopped for an extended period of time. Expected flows during these periods could

Interestingly, there was more variability in the water years which had the largest difference in impacts across all metrics (flood duration, hunt impact score, and flood events) between baseline and BNP scenarios. Under baseline conditions seven unique water years were present in the top four most impactful water years (four possible water years for each metric), while 11 appeared in the Big Notch scenario. The fact that more unique years appeared in the Big Notch subset of peak impact years suggests that the operation of the notch will increase the likelihood of flooding impacts in any given water year.

Moreover, many of the water years that produced a large increase in impacts attributable to the BNP occurred within a single impact class and depth threshold. The variation in water years across impact classes suggests that the study area will experience more moderate floods compared to baseline conditions. These moderate floods did not produce the same extensive levee to levee flooding that occurred in the 1996 and 2005 water years, but they still have substantial impacts to landowner and hunter access, and wetland infrastructure.

3.1 AVERAGED ANNUAL DIFFERENCES BETWEEN SCENARIOS

DU found that the difference between the baseline and BNP scenarios when averaged across all 16 water years, varied significantly across wetland units (Figures 1-9). Some wetland units saw no difference between scenarios, while others saw large impacts within the BNP scenario. DU saw consistency between the berm and six-inch impact classes at the wetland unit level, with across unit trends remaining rather consistent across impact classes. However, trends within the blind impact class were often less aligned with the other two impact classes. General trends within and across each Area (North, Center, South) were also clear; with the North Area showing the largest impact scores (Figures 1-3), the Center Area with intermediate scores (Figures 4-6), and the Southern Area showing marginal scores as a result of the BNP (Figures 7-9). Moreover, wetland units along the eastern margin of all areas tended to have higher impact scores than units along the western margin.

3.2 AVERAGED PEAK BNP IMPACT YEARS

Of the subset of years that had the largest increase in impacts attributable to the BNP, water year 1998 occurred most frequently across all combinations of impact classes and depth thresholds (7; Table 1). Similarly, the water years 2002, 2003, and 2010 all occurred six times, indicating that these water years produced conditions that interacted with the BNP scenario to produce a substantial increase in impacts over baseline conditions. DU presented percentages to compare the additional impacts attributable to the BNP in peak impact years to average impacts under baseline conditions to better compare impacts across wetland units. The percentage value was derived by dividing the averaged increase in impacts attributed to BNP across the subset of four water years by the averaged impacts experienced under baseline conditions. The resulting wetland unit specific percentage value provides a proportional representation of the additional impacts each wetland unit can expect to experience under peak BNP operations. (Figures 10-19). A value of 100% represents the average impacts experienced under the subset of four water years with peak BNP impacts were twice the average impacts under baseline conditions. This examination of additional impacts caused by the BNP highlight wetland units most vulnerable to changes to the Fremont Weir.

Generally, the proportional increase in flood impacts during peak BNP years was the greatest at the six-inch depth threshold. Impacts at the blind depth threshold were the second most frequent change attributable to peak BNP years. These results indicate the addition of the BNP will likely increase the frequency and duration of wetlands experiencing water depths that exceed target depths by approximately six-inches to a foot and a half during peak impact years. A majority of the wetland units within the water years most impacted by the BNP experienced moderate flooding impacts. Wetland units to the west and south within the Northern Area saw larger increase in hunt impacts and flood duration due to the BNP in these water years than other units in the area (Figures 11 and 12). A trend that was present in the Central and Southern Areas was clear; the eastern most wetland units experienced an increase in all impact categories at the berm depth threshold, while units to the west experienced greater impacts at the six-inch depth category. This would be consistent with a general increase in flood depth across the landscape due to the BNP. The model results suggest the largest increase in flood events at the berm threshold will occur primarily in the central and southern wetland units within the Northern Area.

4 DISCUSSION

The analysis of model results highlights the variation in flood impacts caused by different water years. This variation can be seen across wetland units, many of which have average flood duration, hunt impact scores, or flood event counts that are similar or smaller to their standard deviation. Moreover, the figures (1-9) indicate that the impacts of flooding are spatially variable within each region. Some general trends in impacts were present, with the North Area containing wetland units that typically had larger average impacts (flood duration, hunt scores, flood events) across all depth thresholds when compared to the other areas. DU also found that impact scores were typically larger in wetlands located in the eastern margins of each Area, while wetlands located further west tended to have lower scores.

The variation in impacts across water years makes identifying specific impacts attributable to the BNP across multiple years challenging. To better identify the impacts of the BNP, DU focused on the four water years that had the largest difference in cumulative impacts (impacts across all wetland units) between baseline and the BNP scenarios were largest (Tabel 1). These “peak impact years” differed from the water years which resulted in the most extensive flooding during both scenarios as a result of Fremont Weir overtopping (1996 and 2005), and instead highlight what types of impacts are likely to be produced when water flows within the focal region interact with the BNP to produce the additional flooding impacts. This comparison demonstrates how certain wetland units may experience a two-fold increase in impacts in some water years, as a result of the BNP (Figures 10-18). These additional impacts were largest for wetland units that typically experienced low to moderate flooding impacts under baseline conditions.

A critical aspect of understanding the true impact of flooding events, specifically berm overtopping, that landowners experience is the additional loss of days due to the time required to prepare for a flood. This preparation phase often requires landowners to move equipment to avoid damage or loss. Moreover, once water surface elevations return to normal levels, roads and other infrastructure required for access and hunting require additional days until they can be safely used. Our interviews with landowners suggest that, in general, an additional 14-20 days of lost access is added to flood events when accounting for the preparation and return phase. DU considered all flood events would require approximately the same amount of additional time to prepare and recover from, so all scores are biased by the same amount. DU didn’t account for these times since DU is more focused on comparing flood events, and water years within the model itself, to avoid magnifying model biases by extrapolating to real-world circumstances. Instead, the number of flood events could be used as a proxy to account for these additional lost days, where one flood event is likely equivalent to 14-20 additional days of lost access. Due to the complexities associated with road access, soil moisture, rate of flooding, and antecedent conditions, DU chose to not modify scores directly to avoid introducing additional assumptions.

It should be noted that this assumption is violated when the number of flood events occurring within a year differs amongst scenarios, which is why DU included flood events as a metric. The insight gained by examining this metric is reduced when comparing averages across multiple years, particularly when comparing across scenarios which can increase flood duration causing multiple separate flood events to blend into a single prolonged flood event. Because of the complexities surrounding flood events, additional examinations into what conditions combine with the BNP to create additional flood events are needed.

Modifications to berms, water control structures, and changes to the watershed in areas outside of the focal region all impact the accuracy of predictions made using model data. Similarly, future changes to the wetland units within the focal region have the potential to modify water flow such that other wetland units see changes as well, since the system is connected. If you modify one area, other areas are impacted. There is the risk that modification to one region to reduce impacts results in increased impacts to another region.

To better understand real-world flood outcomes that are caused by the BNP requires monitoring and data collection. This real-world data would allow for model corrections or updates that could be useful in determining outcomes resulting from future changes to the system. Moreover, real-time data collection of river-stage and water flows can reduce the consequences of flooding that landowners currently experience, by serving as a monitoring system that can accurately alert landowners to incoming floods.

5 RECOMMENDATIONS/PROPOSED IMPROVEMENTS

DU met with many landowners or key representatives for easement properties. These meetings were held to better understand site conditions, operations, and procedures for flood evacuation. The meetings provided DU with important perspectives to inform the analysis as well as potential improvements to offset impacts. General notes and key takeaways from our meetings were captured and incorporated into impact reduction recommendations when feasible. Attention is directed towards the enhancement of drainage infrastructure, facilitated by the strategic installation of water control structures and targeted enhancements to existing ditches. Additionally, access road and berm improvements to support winter access and provide more predictable road conditions are proposed.

As previously discussed, the model represents a highly drained system that does not fully capture the drainage challenges currently present within the bypass. While these recommendations focus substantially on improving drainage within the system, it is not possible to implement the measures required to achieve the level of drainage represented in the model. Based on DU's observations, the results likely indicate that the impacts described represent a best-case scenario, and the proposed improvements are not likely adequate to fully offset additional flooding resulting from the operation of the BNP. A more refined hydraulic model would likely reduce the degree of uncertainty.

DU has provided the USFWS with conceptual restoration exhibits and associated construction cost estimates for each of the three analysis areas. While the below recommendations are high level, DU has developed approximately 137 possible improvements that span the study area. The exhibits are not provided in this document as they occur on private lands and have not been vetted by the corresponding landowners. DU is working with the USFWS to refine and prioritize the list of potential improvements having discussed many of the potential improvements with landowners.

5.1 NORTH AREA

The northern region exhibits significant drainage limitations due to the plethora of water sources inundating the area. Floodwaters converge from various directions, ranging from the overtopping of tule canal banks on the east to inundation from Willow Creek on the west, and during higher flood flow levels, from Wallace Weir and Fremont Weir. Ducks Unlimited recommends enhancing drainage capacity by augmenting ditch/canal capacity and enlarging water control structures. Many existing structures, while sufficient to convey water for managed seasonal wetlands in controlled water delivery systems, are undersized to convey flows during flood events. These structures prove inadequate in conveying flows as water levels approach top of berms elevations. If water levels on one side of the berm drain faster than the opposing side, a head differential occurs and produces increased velocities, typically resulting in scouring of material on the tops and side slopes of berms. Increasing drainage capabilities will reduce this effect and overall maintenance of infrastructure.

Recommendations are primarily focused on increasing drainage, with an increased emphasis on three main north-south running canals. An example of a substantial improvement is a recommendation to improve a crossing over Willow Creek on the westerly side of the bypass. This crossing consists of several large concrete pipes and the crossing is the main access point for northern area landowners. This area is plagued by debris accumulation further slowing flows and exacerbating overland flooding. The crossing is the lowest point, overtops before the adjacent sections of the road, and constitutes an access restriction. DU recommends replacing this crossing with modular pre-cast concrete bridge structure(s) to elevate the crossing.

5.2 CENTER AND SOUTH AREA

While results indicate that impacts are typically higher in the northern area, the model is missing approximately 25,000 acre-feet of water. Due to this, the duration and potential magnitude of impacts for areas further downstream are likely underestimated. Water fills wetland units and other lands to the north that would otherwise already contain water, and flows would increase downstream sooner and with more volume than represented.

The center area region exhibits drainage limitations due to lower elevations and larger tidal influence. Flood waters in this area are typically more predictable and associated with a set water surface elevation at Lisbon Weir. Low level flood impacts are typically attributed to overbank flooding from the Toe Drain. Improvement recommendations to this area include establishing improved drainage, berm and road elevations improvements, improving road conditions, and rehabilitating and installing pump stations. Many of these properties are reliant on others to flood and drain. DU recommends establishing greater independent flood and drainage for individual landowners to reduce conflict and allow property managers greater control over site specific habitat needs.

5.3 MONITORING AND USFWS REVERIFICATION OF COMPATIBLE USE

Per USFWS, compatible use determinations must be re-authorized every ten years. Due to the high level of uncertainty surrounding model simulations, continued changes to the watershed, as well as the incorporation of climate change in the operations of the Project, the effects of the Project should be monitored on an annual basis and reviewed at no later than this 10-year period. One potential way to monitor effects would be to develop a remote sensing monitoring program to better understand the realized impacts of the Project. Long-term remote sensing could be utilized to collect data on water flows, water surface elevation, and vegetation communities, as well as data that captures the impacts that landowners experience. The long-term monitoring data would provide a basis to conduct an analysis to determine how the operation of the BNP impacts vegetation communities. This could be feasible by monitoring vegetative communities within the study area for 10 years to confirm both drought and high rainfall years are captured. Recent work conducted using a remote sensing approach to evaluate changes in wetland plant communities and waterfowl food production in response to drought has demonstrated a framework that could be applied (Byrd et al. 2020).

5.4 LONG-TERM MAINTENANCE FUND

The proposed infrastructure improvements intended to mitigate the impact of the Project come with significant long-term management costs. DU suggests the establishment of a stewardship fund to generate annuity-like financing for future maintenance and replacement needs. By using a Property Analysis Record (PAR) or similar calculator to determine the capital needed to establish the stewardship fund, sustainability can be provided beyond the completion of the implementation phase. DU conducted a preliminary estimate for a stewardship fund based on the cost of the proposed improvements, minus the existing facility's value. Establishing an endowment ultimately allows stakeholders to proactively address maintenance challenges, protecting the project's viability and enhancing its long-term impact. While this approach requires further refinement, DU strongly recommends setting up an endowment for the future operation of proposed improvements.

5.5 WATER LEVEL DATA STATION

Water level elevations for flood inundation events for the Center and South areas are determined by stage elevation at the Lisbon Weir. Many landowners in these areas utilize the California Data Exchange Center (Cdec) river stage data to determine when water levels will exceed berm and equipment elevations in planning for floods. However, the north area flooding is more variable than areas to the south due to a variety of inputs. No water level data station is available to gauge when roads and other equipment will be flooded out. DU recommends developing either a new Cdec station just north of the causeway or the installation of a smaller Onset Hobo Data station or similar that landowners have real-time data access to. Having access to this level of information could save landowners thousands of dollars in equipment loss and repair. In addition to the water level data station, it is recommended that an automated communication system be set up for the public to be notified when BNP operations are anticipated and when BNP operations occur.

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7 LINKS PROVIDED

Cdec	https://cdec.water.ca.gov/webgis/?appid=cdecstation&sta=LIS

TABLES

Table 1. Four Most Impacted Years

The cumulative impact of each water year was calculated by summing impact scores across all wetland units. A single cumulative impact score was produced for each unique combination of impact category (Hunt Impact Score, Flood Events, Duration) and depth category (Berm, Blind, Six-inch). The four most impactful water years are presented in descending order, with the highest cumulative impact score being present first. The difference in cumulative water year impact scores between both scenarios was used to determine which water years had the greatest increase in impacts attributable to the BNP. The difference between scenarios were then used to rank water years, with the largest differences between scenario scores by water year presented in descending order, where the water year with the largest difference being presented first.

Years Most Impacted under Baseline Conditions			**Years with the Largest Difference Between the BNP and Baseline Scenarios**		
Hunt Impact Score			***Hunt Impact Score***		
Berm	Blind	Six-inch	Berm	Blind	Six-inch
1996	1996	1996	2002	1998	1998
2005	2005	2005	2003	2002	2002
1997	1997	1997	2010	2010	2010
1999	2003	2002	2009	2003	2003
Flood Events			***Flood Events***		
Berm	Blind	Six-inch	Berm	Blind	Six-inch
2005	2005	2005	2004	1998	1998
1996	2002	2003	2009	2008	2008
1998	1996	2002	2003	2000	2004
2002	2003	1996	1998	2004	2006
Duration			***Duration***		
Berm	Blind	Six-inch	Berm	Blind	Six-inch
1997	1996	1996	2002	1998	1998
1996	1997	2005	2003	2002	2002
2005	2005	1997	2005	2010	2010
1999	2003	2003	2010	1996	2003

Table 2. Averaged Increase in Impacts by Region

The averaged (across all 16 water years) annual increase in impacts attributable to the BNP are presented by impact type (flood duration, flood events, hunting impact score) and depth threshold (maximum berm elevation, average blind elevation, and six-inch increase), averaged across each of the three regions (North, Center, and South) within the project area.

Region	Number of Wetland Units Contained	Average additional days of annual flooding due to the BNP			Average additional annual flood events due to the BNP			Average increase in annual hunting impact score due to the BNP		
		Berm	Blind	Six Inch	Berm	Blind	Six Inch	Berm	Blind	Six Inch
North	23	2.2	7.1	10.9	0.1	0.3	0.3	9.4	26.7	39.5
Center	17	1.7	4.5	5.9	0.1	0.1	0.2	7.0	16.9	21.6
South	15	0.6	1.0	3.2	0.0	0.0	0.1	2.7	4.1	12.3

Table 3. Averaged Increase in Peak Impacts by Region

The average percentage increase in additional impacts over baseline conditions, attributable to the BNP during peak impact years. Values were calculated at the wetland unit level by using Equation 1. Percentages are presented by impact type (flood duration, flood events, hunting impact score) and depth threshold (maximum berm elevation, average blind elevation, and six-inch increase), averaged across each of the three regions (North, Center, and South) within the project area.

Region	Number of Wetland Units Contained	Percent increase in flood duration caused by BNP during peak impact years			Percent increase in flood events caused by BNP during peak impact years			Percent increase in hunting impact score caused by BNP during peak impact years		
		Berm	Blind	Six Inch	Berm	Blind	Six Inch	Berm	Blind	Six Inch
North	23	29.8	54.8	66.8	31.0	61.8	75.9	37.6	62.4	72.4
Center	17	21.5	38.4	46.7	21.0	56.1	67.8	25.6	46.0	53.3
South	15	10.1	9.8	29.4	12.0	5.6	30.9	11.9	15.1	37.1

Table 4. Averaged Increase in Peak Impacts by Region

The additional or increase in flooding impacts across all impact categories (flood duration, flood events, and hunt impact score) and depth thresholds (berm, blind, six inch) attributable to the operation of the Big Notch during peak impact years. Peak impact years are defined by the four water years where cumulative scores across all wetland units under the big notch scenario produced the largest difference. Average increase values are in **bold** followed by (minimum and maximum) values.

Region	Number of Wetland Units Contained	Additional days of flooding			Additional flood events			Increase in hunting impact score		
		Berm	Blind	Six Inch	Berm	Blind	Six Inch	Berm	Blind	Six Inch
North	23	**4.96** (0-17.8)	**13.66** (0-25)	**21.17** (16-26)	**0.29** (0-1.25)	**0.74** (-0.25-1.75)	**0.95** (0-2)	**21.75** (0-75.25)	**55.22** (0-95.25)	**82.20** (67-95.75)
Center	17	**3.63** (0-16)	**9.07** (0-25)	**12.03** (0-21.5)	**0.21** (-0.25-1.00)	**0.59** (0-1.25)	**0.69** (0-1.33)	**15.25** (0-67)	**38.77** (0-77.25)	**49** (0-80.25)
South	15	**1.58** (0-12.3)	**1.63** (0-12)	**6.41** (0-18.3)	**0.1** (0-0.75)	**0.05** (0-0.5)	**0.38** (-1-1.67)	**6.47** (0-56.75)	**8.6** (0-57.50)	**27.90** (0-72)

FIGURES

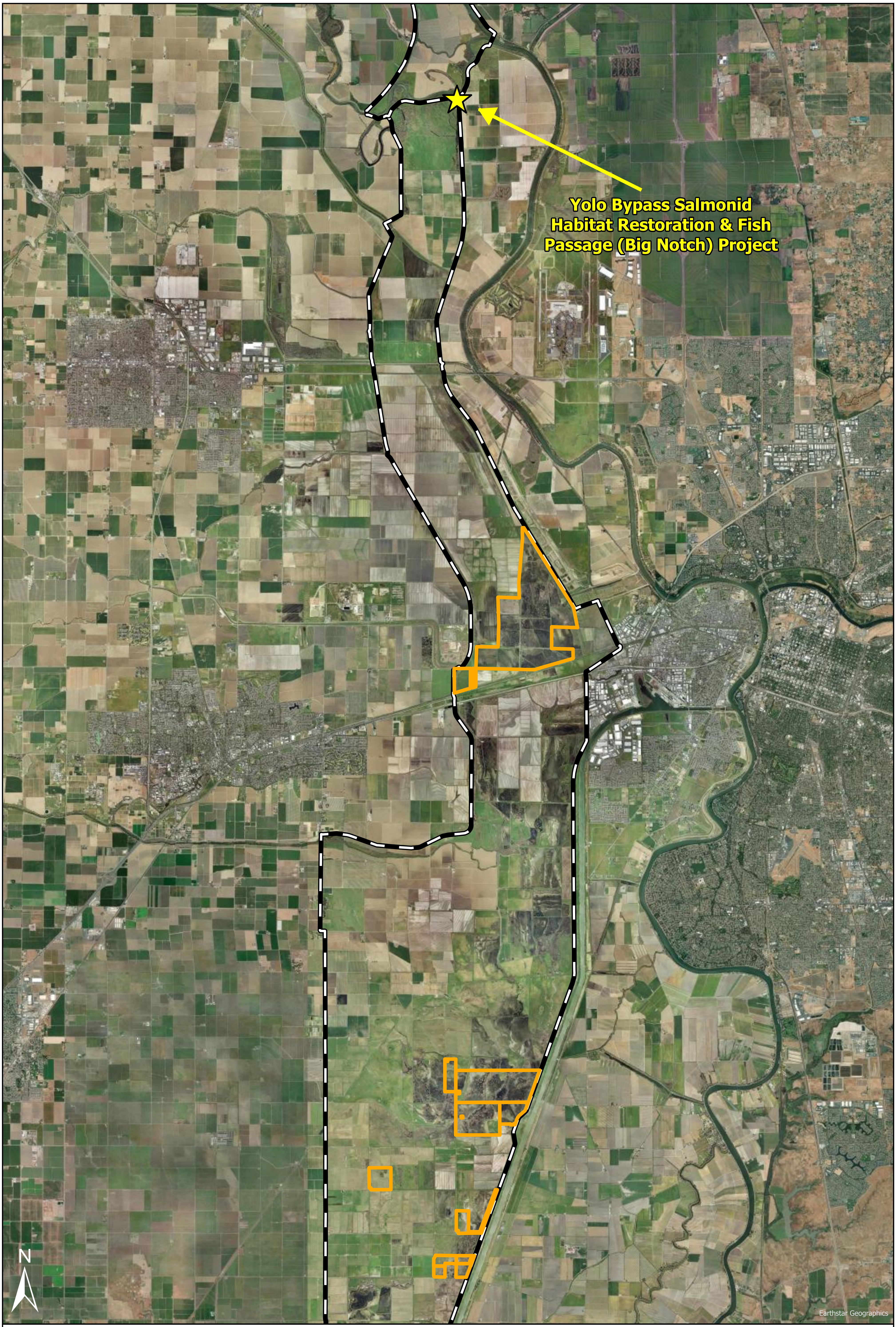


Figure A. USFWS Easement Location Map

🟧 USFWS Easement Boundaries

▨ Yolo Bypass Levees

Figure B: An illustration of the water depth thresholds considered in this analysis. Target Depth within each wetland unit was assumed to be approximately 12 inches deep, following the traditional guidelines of wetland management guides to provide wintering habitat for migratory waterfowl. The six-inch increase threshold would correspond to an approximate depth of 18 inches, a depth that is beyond what most dabbling ducks forage within, resulting in a reduction in waterfowl use. The second depth threshold is the average elevation of hunting blinds within the managed wetland unit. Water depths beyond this elevation would prevent proper use of these structures. The final depth threshold is the maximum berm elevation surrounding the wetland unit. Water would be moving over the top of the exterior berm once the threshold is surpassed, damaging the berm and preventing safe use of the wetland and any type of management of the wetland unit.

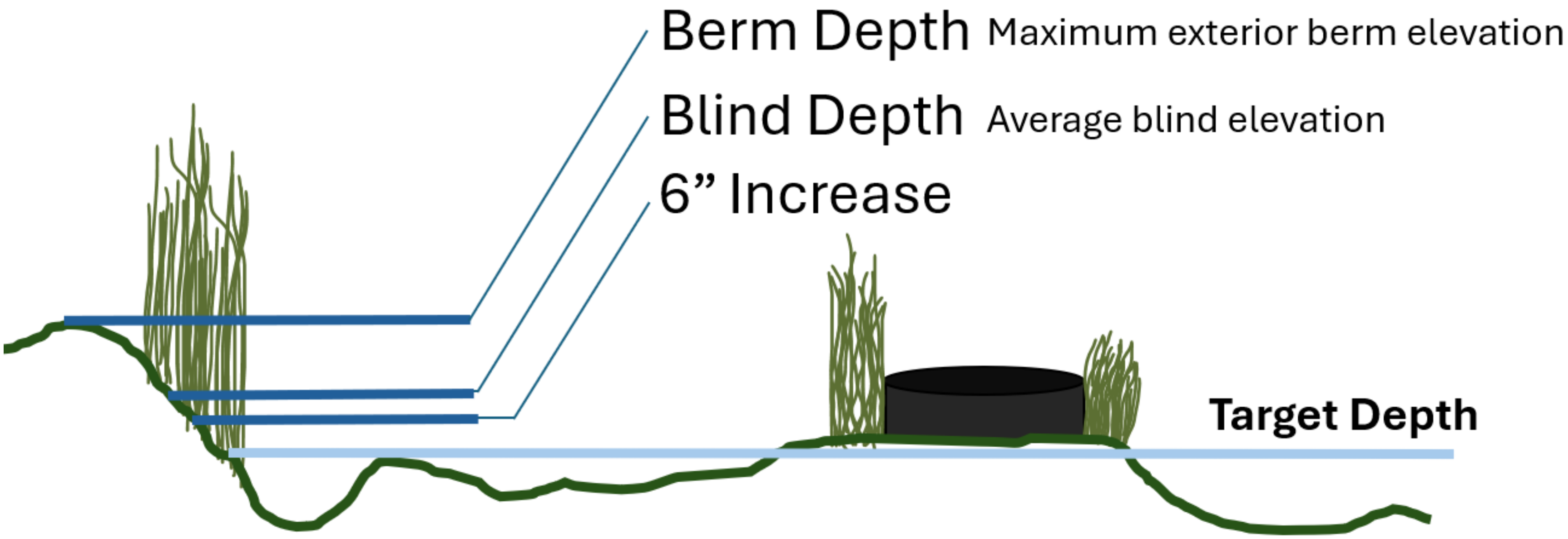
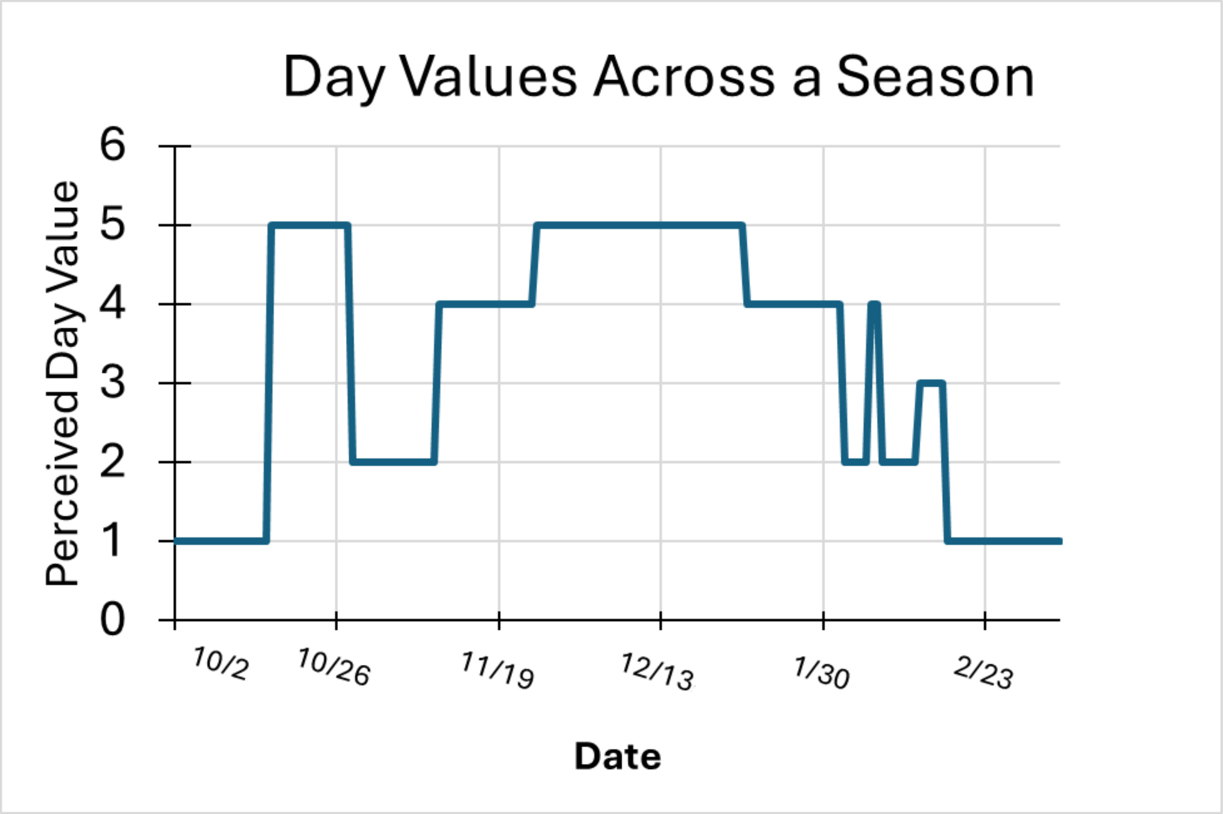


Figure C: Each day between Oct. 2 – Mar. 15 was assigned a value ranging between one and five. The more valuable a day is, as perceived by landowners, the larger the value. Specific dates for the waterfowl hunting season, including opening day, closure of the season, junior hunt weekend, veterans hunt weekend, and late goose season, are based on the balance of state for the 2023-2024 season. These dates are subject to change due to the adaptive harvest management framework currently used by the U.S. Fish and Wildlife Service.



Equation 1: The equation used to calculate the proportional increase in impacts attributable to the BNP in peak impact years (four water years) over average baseline conditions (sixteen water years) for each unique combination of depth threshold and impact category at the wetland unit level. The difference between impact scores by scenario for the subset of peak impact years was averaged across all four peak impact years for each wetland, then divided by the average baseline impact score. The resulting proportional increase (expressed as a percentage) represents the additional impacts above baseline that could be expected to occur for 25% of the water years when the BNP is operating.

$$Peak\ Mean\ Difference = \frac{\sum_{w=1}^{4}(\text{Impact Score}_{\text{Big Notch}} - \text{Impact Score}_{\text{Baseline}})}{4}$$

$$\text{Proportional Increase} = \frac{Peak\ Mean\ Difference}{Average\ Baseline\ Impact\ Score}$$

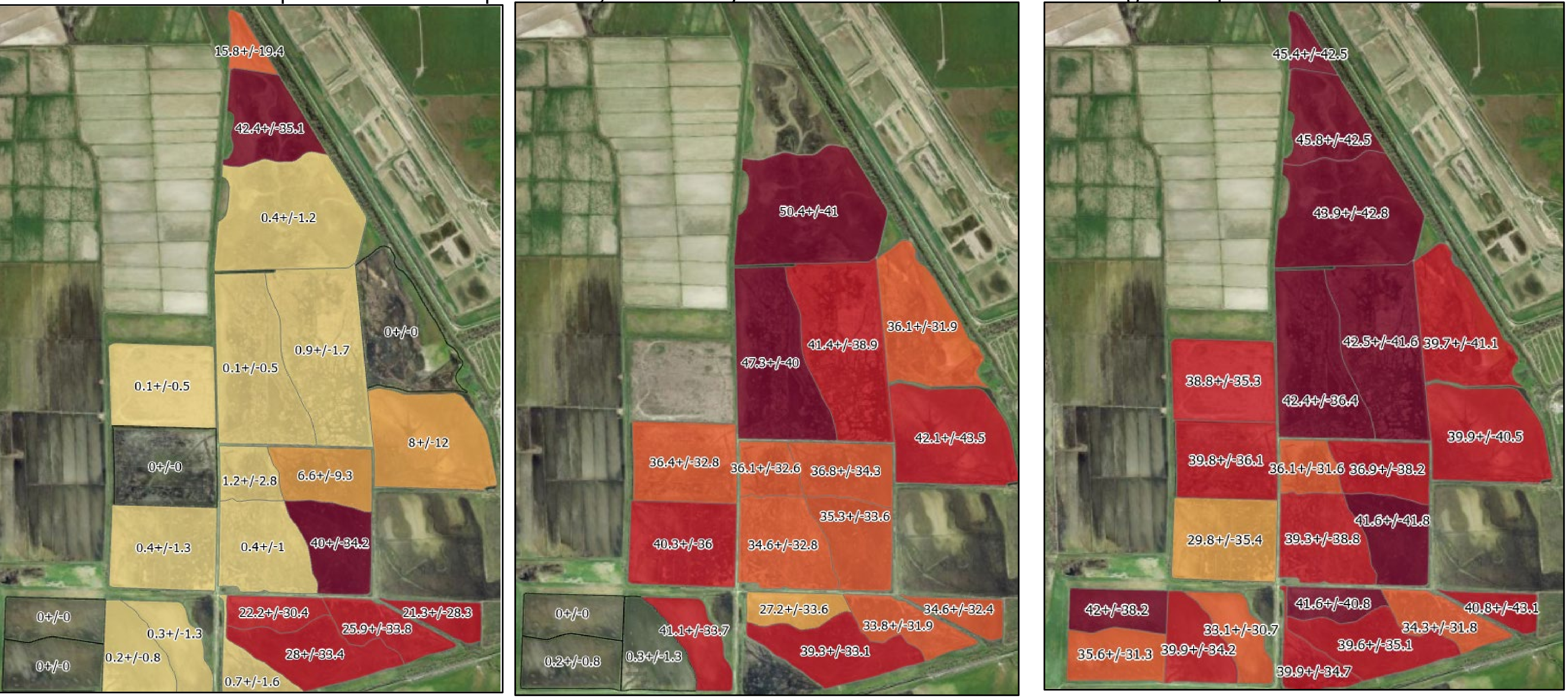
Figure 1: Averaged annual difference of flood duration between baseline and big notch scenarios, by depth threshold for wetland units in the North Area. Unit specific days are presented, followed by standard deviation values. Shading corresponds to values.

Berm

Blind

Six Inch

Figure 2: Averaged annual difference of hunt impact score between baseline and big notch scenarios, by depth threshold for wetland units in the North Area. Unit specific scores are presented, followed by standard deviation values. Shading corresponds to values.

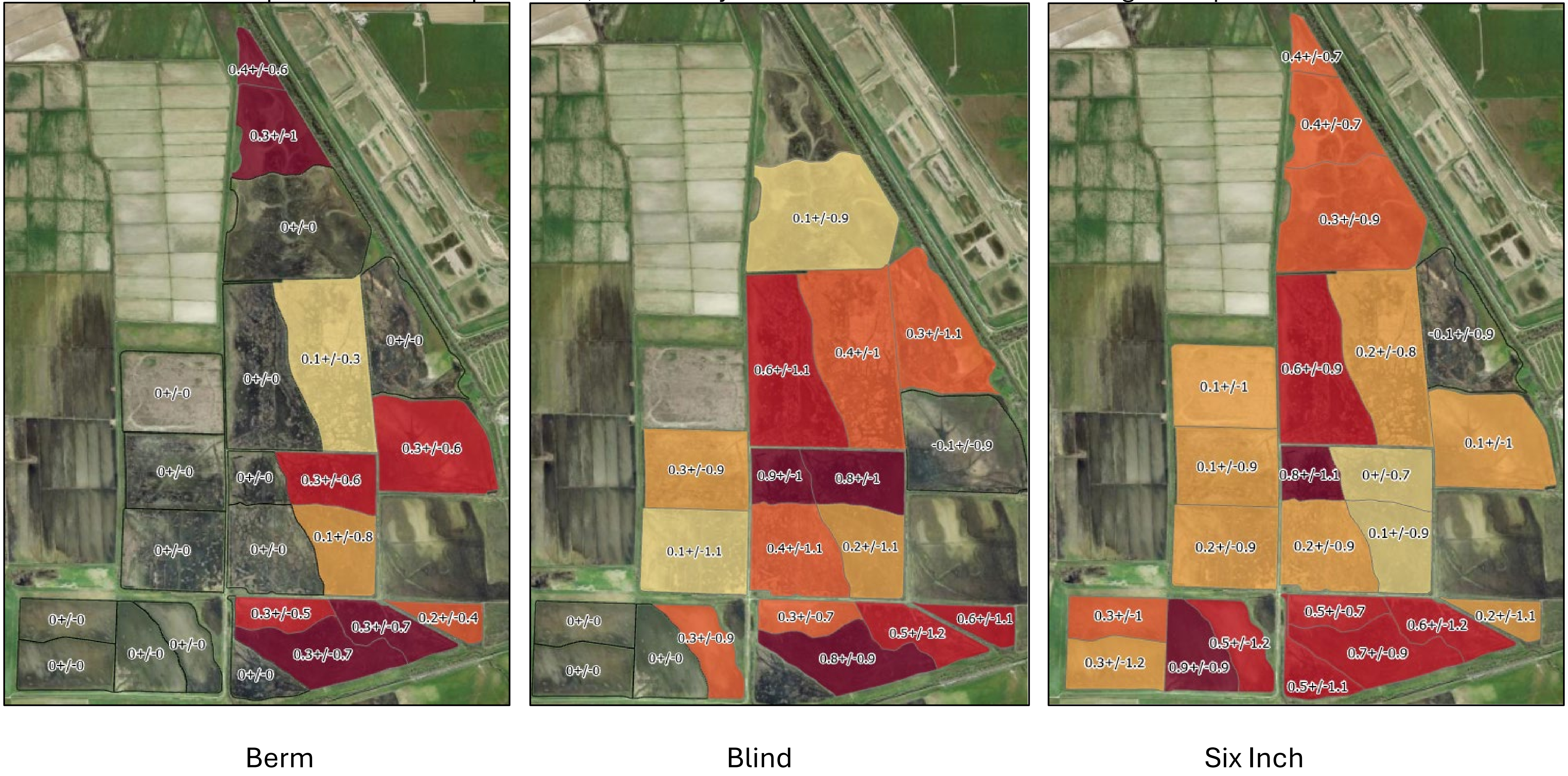


Berm

Blind

Six Inch

Figure 3: Averaged annual difference of flood event count between baseline and big notch scenarios, by depth threshold for wetland units in the North Area. Unit specific values are presented, followed by standard deviation values. Shading corresponds to values.

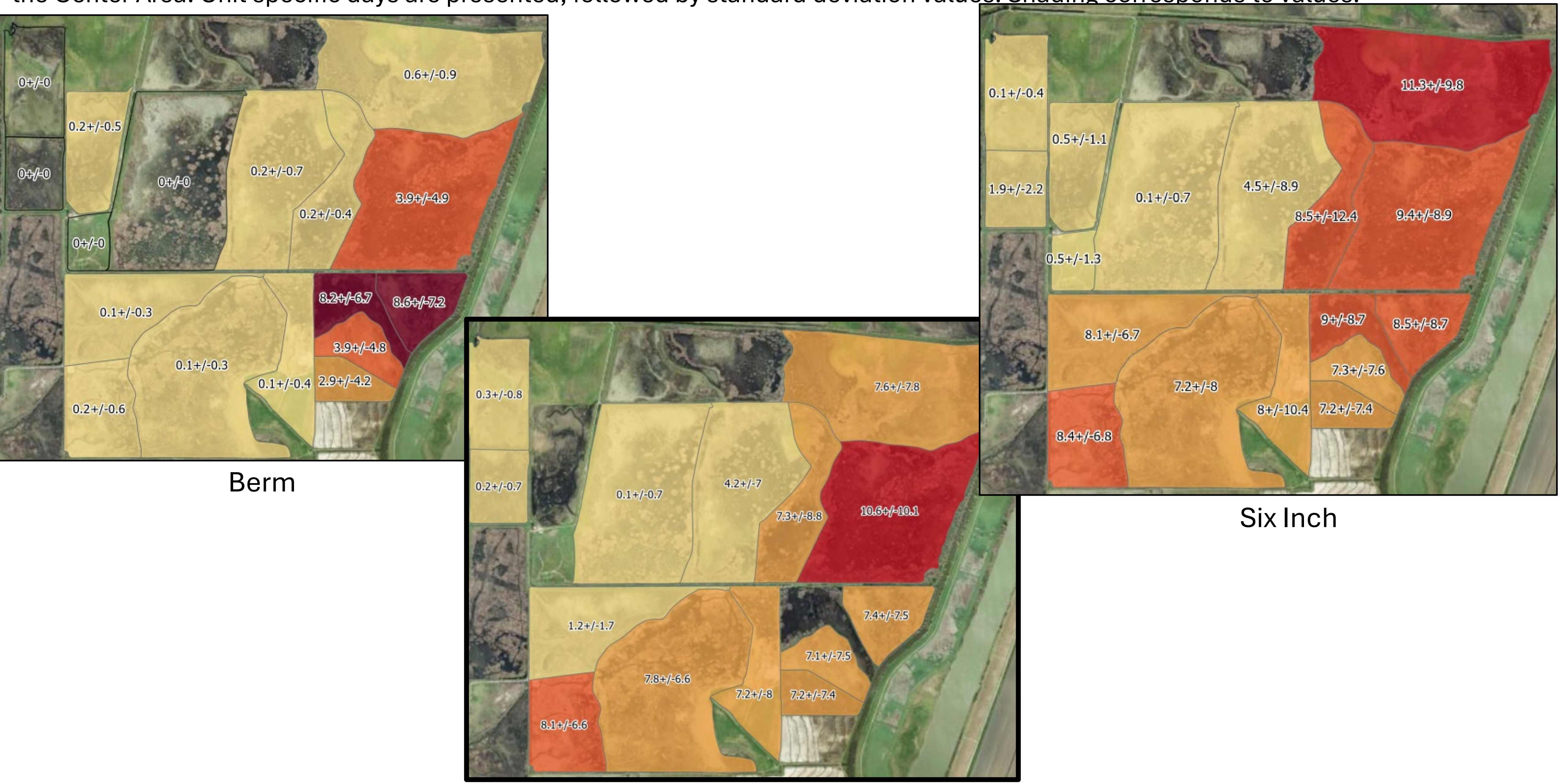


Berm

Blind

Six Inch

Figure 4: Averaged annual difference of flood duration between baseline and big notch scenarios, by depth threshold for wetland units in the Center Area. Unit specific days are presented, followed by standard deviation values. Shading corresponds to values.

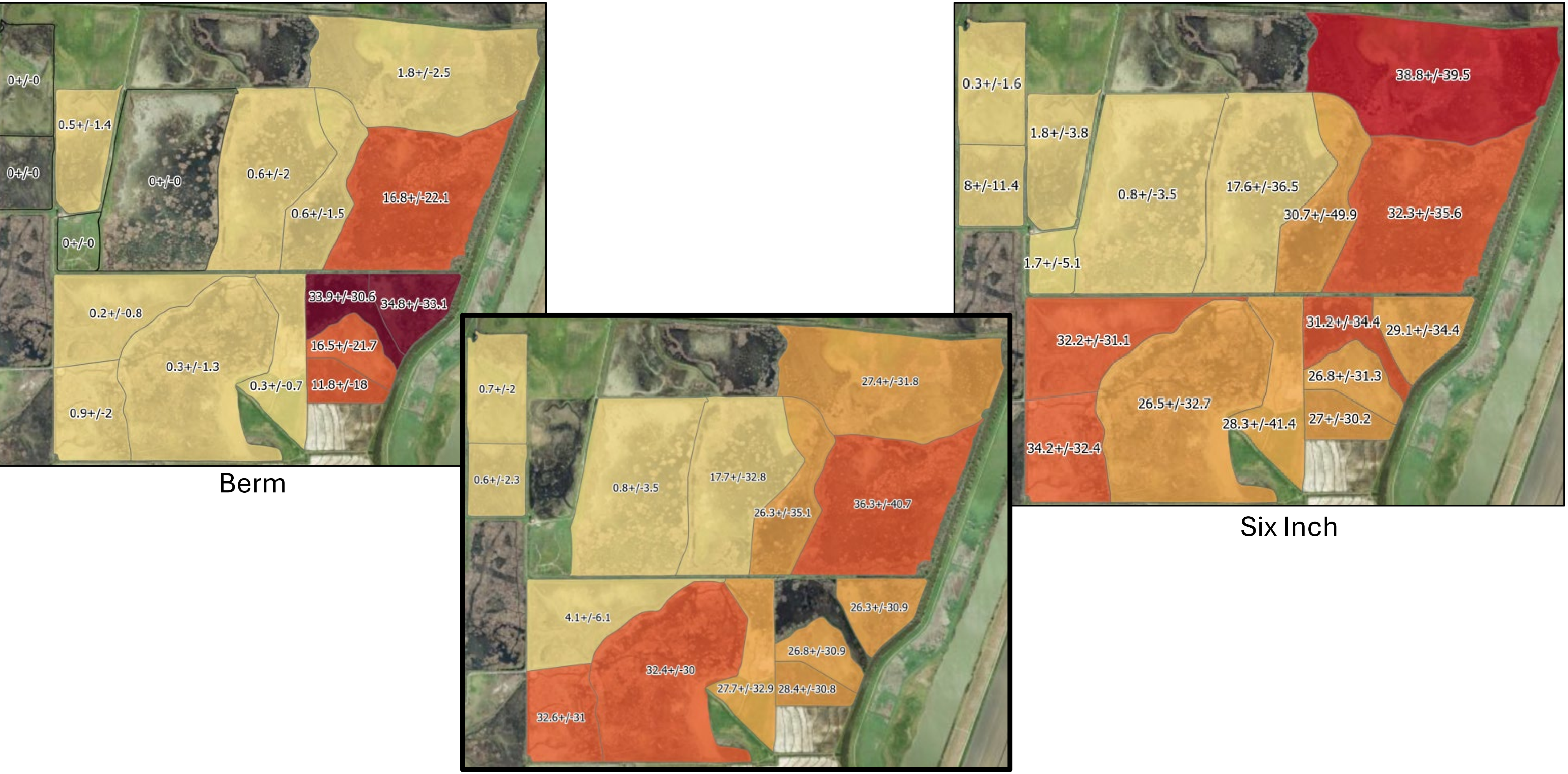


Berm

Blind

Six Inch

Figure 5: Averaged annual difference of hunt impact score between baseline and big notch scenarios, by depth threshold for wetland units in the Center Area. Unit specific scores are presented, followed by standard deviation values. Shading corresponds to values.



Berm

Six Inch

Blind

Figure 6: Averaged annual difference of flood event count between baseline and big notch scenarios, by depth threshold for wetland units in the Center Area. Unit specific values are presented, followed by standard deviation values. Shading corresponds to values.

Berm

Blind

Six Inch

Figure 7: Averaged annual difference of flood duration between baseline and big notch scenarios, by depth threshold for wetland units in the South Area. Unit specific days are presented, followed by standard deviation values. Shading corresponds to values.

Berm

Blind

Six Inch

Figure 8: Averaged annual difference of hunt impact score between baseline and big notch scenarios, by depth threshold for wetland units in the South Area. Unit specific scores are presented, followed by standard deviation values. Shading corresponds to values.

Berm

Blind

Six Inch

Figure 9: Averaged annual difference of flood event count between baseline and big notch scenarios, by depth threshold for wetland units in the South Area. Unit specific values are presented, followed by standard deviation values. Shading corresponds to values.

Berm

Blind

Six Inch

Figure 10: Proportional increase in flood duration over baseline conditions attributable to the big notch under maximum impact years. Maximum impact water years defined as the four years which had the largest cumulative difference in duration between baseline and big notch scenarios. Values are presented for each depth threshold by wetland unit in the North Area. Shading corresponds to values.

Berm

Blind

Six Inch

Figure 11: Proportional increase in hunt impact score over baseline conditions attributable to the big notch under maximum impact years. Maximum impact water years defined as the four years which had the largest cumulative difference in scores between baseline and big notch scenarios. Values are presented for each depth threshold by wetland unit in the North Area. Shading corresponds to values.

Berm

Blind

Six Inch

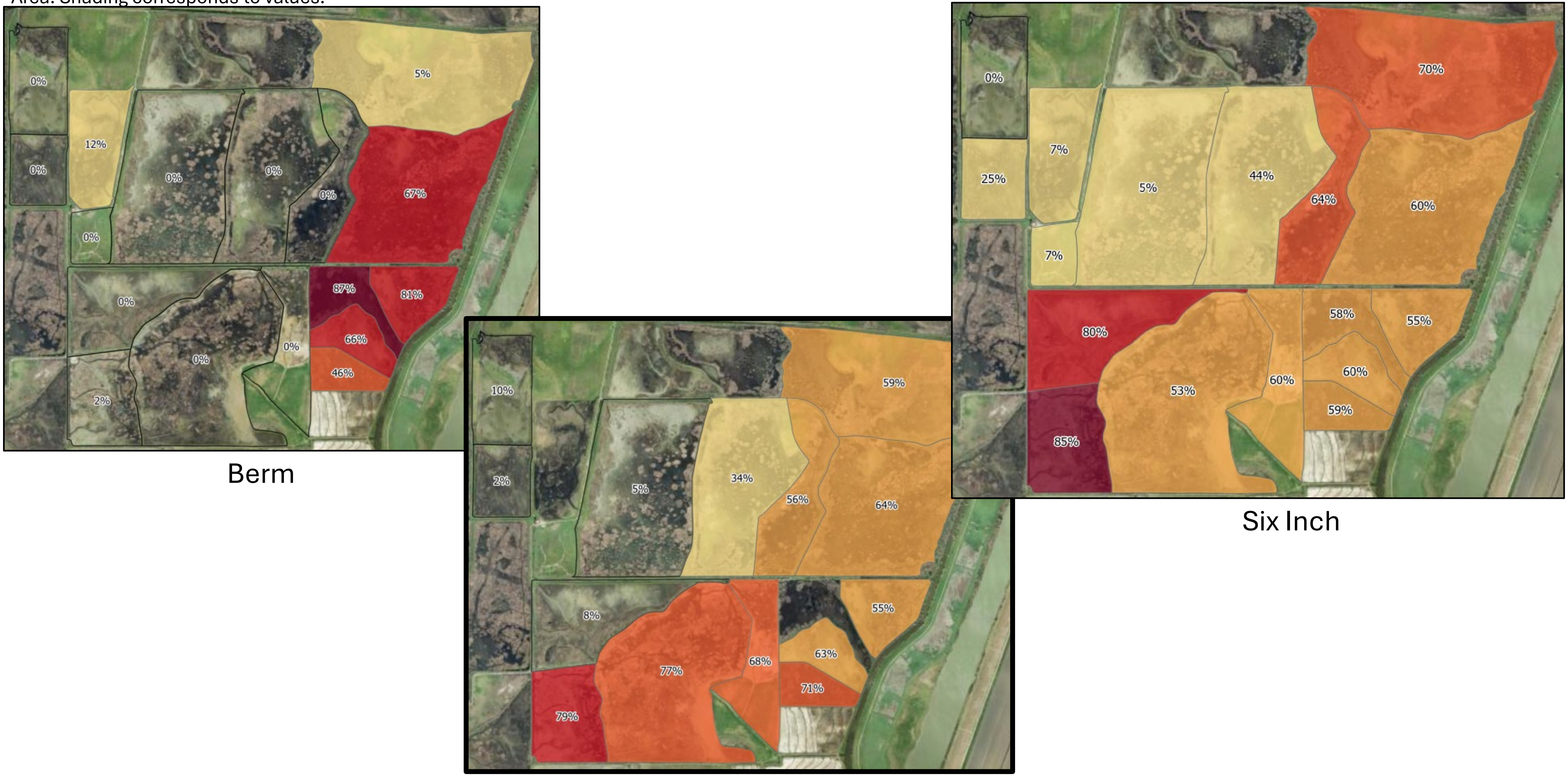
Figure 12: Proportional increase in flood event count over baseline conditions attributable to the big notch under maximum impact years. Maximum impact water years defined as the four years which had the largest cumulative difference in flood events between baseline and big notch scenarios. Values are presented for each depth threshold by wetland unit in the North Area. Shading corresponds to values.

Berm

Blind

Six Inch

Figure 13: Proportional increase in flood duration over baseline conditions attributable to the big notch under maximum impact years. Maximum impact water years defined as the four years which had the largest cumulative difference in duration between baseline and big notch scenarios. Values are presented for each depth threshold by wetland unit in the Center Area. Shading corresponds to values.

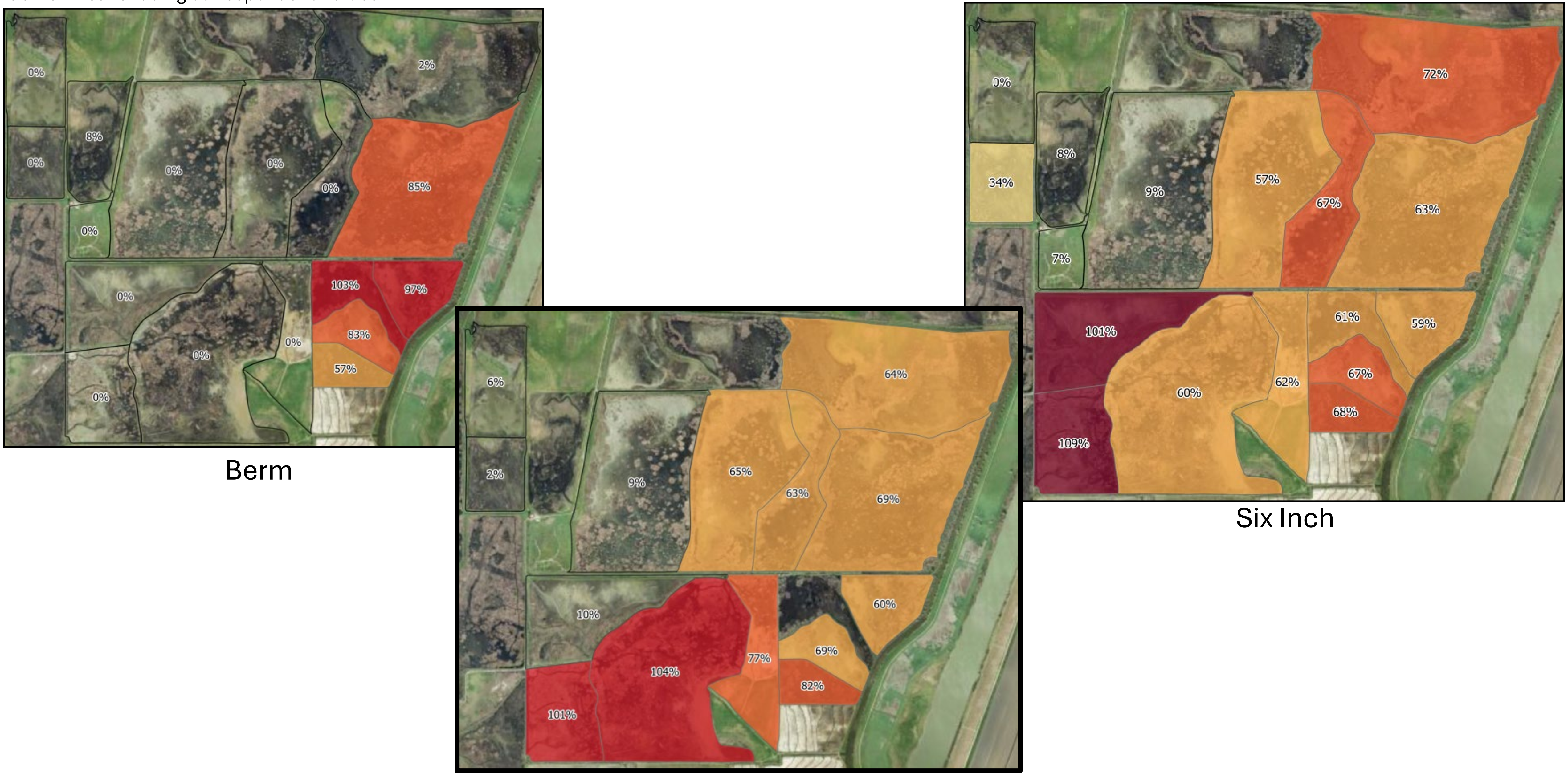


Berm

Six Inch

Blind

Figure 14: Proportional increase in hunt impact score over baseline conditions attributable to the big notch under maximum impact years. Maximum impact water years defined as the four years which had the largest cumulative difference in scores between baseline and big notch scenarios. Values are presented for each depth threshold by wetland unit in the Center Area. Shading corresponds to values.

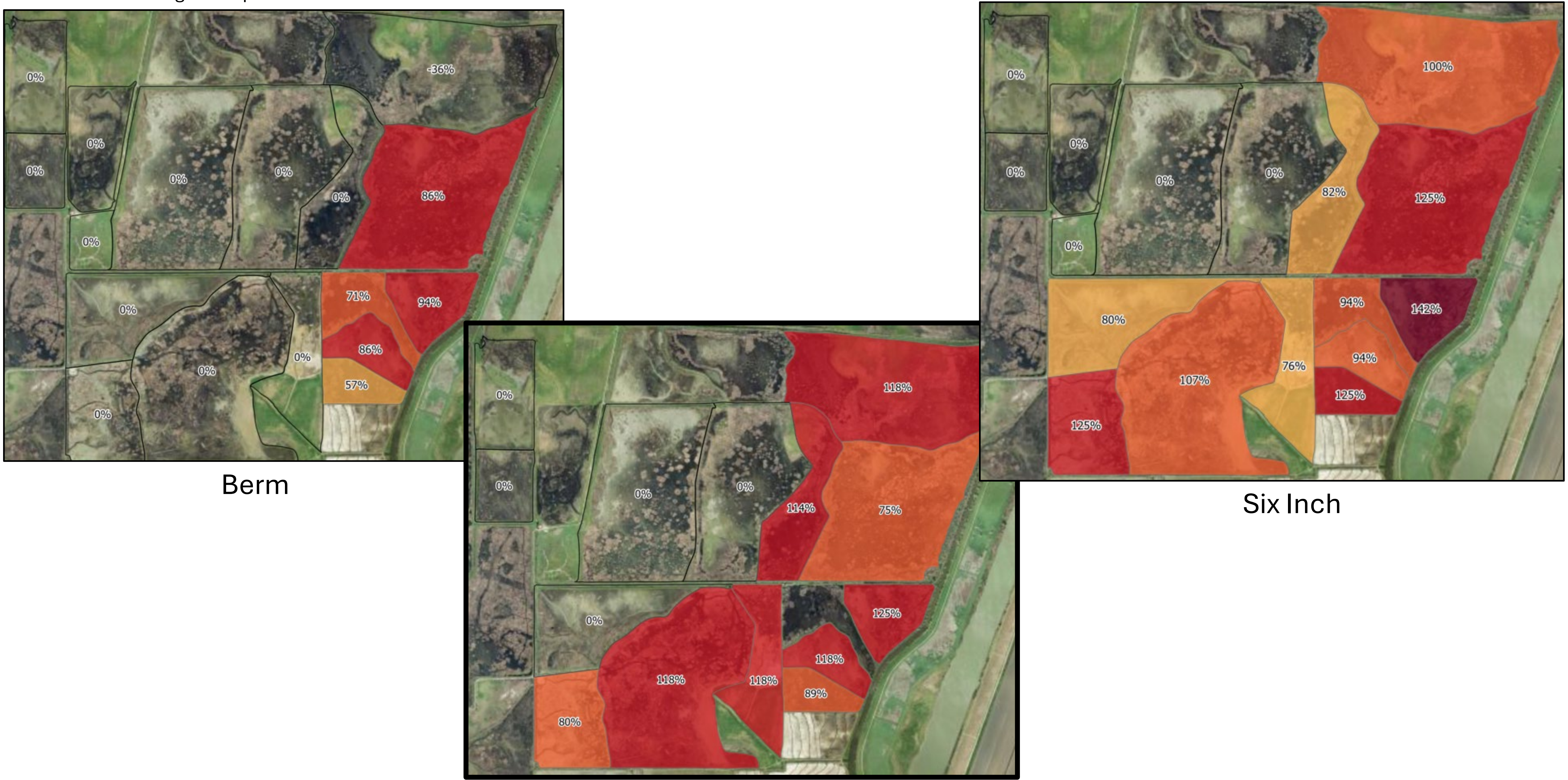


Berm

Blind

Six Inch

Figure 15: Proportional increase in flood event count over baseline conditions attributable to the big notch under maximum impact years. Maximum impact water years defined as the four years which had the largest cumulative difference in flood events between baseline and big notch scenarios. Values are presented for each depth threshold by wetland unit in the Center Area. Shading corresponds to values.



Berm

Blind

Six Inch

Figure 16: Proportional increase in flood duration over baseline conditions attributable to the big notch under maximum impact years. Maximum impact water years defined as the four years which had the largest cumulative difference in duration between baseline and big notch scenarios. Values are presented for each depth threshold by wetland unit in the South Area. Shading corresponds to values.

Berm

Blind

Six Inch

Figure 17: Proportional increase in hunt impact score over baseline conditions attributable to the big notch under maximum impact years. Maximum impact water years defined as the four years which had the largest cumulative difference in scores between baseline and big notch scenarios. Values are presented for each depth threshold by wetland unit in the South Area. Shading corresponds to values.

Berm

Blind

Six Inch

Figure 18: Proportional increase in flood event count over baseline conditions attributable to the big notch under maximum impact years. Maximum impact water years defined as the four years which had the largest cumulative difference in event count between baseline and big notch scenarios. Values are presented for each depth threshold by wetland unit in the South Area. Shading corresponds to values.

Berm

Blind

Six Inch