UNITED STATES DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE

February 11, 2016

Lower Snoqualmie River, WA WRP/FPE Drainage Assessment

REPORT OF FINDINGS

Project: Surface Water Drainage / Off Site Impact Study
Location: Snohomish County, Washington
Authority: WRP/EWP-FPE/CTA

LAWRENCE ALAN JOHNSON
STATE OF WASHINGTON
00392050
REGISTERED
PROFESSIONAL ENGINEER

2-11-2016

Prepared by: Lawrence A. Johnson, P.E.
State Conservation Engineer

LAWRENCE JOHNSON Digitally signed by LAWRENCE JOHNSON
DN: c=US, o=U.S. Government, ou=Department of Agriculture, cn=LAWRENCE JOHNSON, 0.9.2342.19200300.100.1.1=12001000426382
Date: 2016.02.11 09:00:34 -08'00'

The Natural Resources Conservation Service provides leadership in a partnership effort to help people conserve, maintain, and improve our natural resources and environment.

An Equal Opportunity Provider and Employer

This page is intentionally blank for pagination purposes

Lower Snoqualmie River, WA
WRP/FPE Drainage Assessment

Assessment Description: The purpose of this report is to describe the micro-hydrology characteristics of the study area. While there have been multiple hydrologic and hydraulic studies completed they do not provide the micro level perspective on the day to day drainage characteristics. This assessment will draw information and conclusions from the following reports and NRCS design folders:

1. Pearson's Eddy WRP Hydraulic Analysis; dated March 6th, 2009, by Tetra Tech
2. Hydraulic Offsite Impacts Analysis related to the Establishment of Vegetation on the Person Eddy WRP Easement and Jenson FPE; date 5-2-2011, by Daniel Moore, P.E. NRCS Hydraulic Engineer
3. Hydraulic Impact Analysis of WRP Project features along Pearson Eddy Slough, date July 2012, by Daniel Moore, P.E. NRCS Hydraulic Engineer
4. Addendum to the Hydraulic Impact Analysis of WRP Project features along Pearson Eddy Slough, date November 2015, by Daniel Moore, P.E. NRCS Hydraulic Engineer
5. NRCS Pearson Eddy construction drawings and specifications approved 3-31-2014.

Objectives: This report shall summarize the anticipated effects that the Wetland Reserve Program (WRP) easement restoration and Emergency Watershed Protection - Floodplain Easement Program (FPE) restoration goals may have on the surrounding properties. Specifically addressed in this report are the offsite effects that the proposed and completed restoration activities are anticipated to have on the day to day drainage functionality within the study area for the near and long term.

Background: There are three NRCS easements, two under WRP and one FPE, within the study area as shown in figure 1. All three of the easements are permanent, NRCS has acquired the right to restore and maintain the easements within the two NRCS authorized programs. Each program has unique requirements.

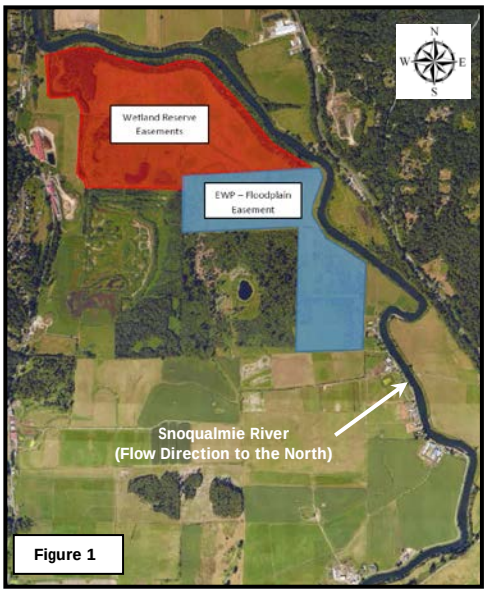

Figure 1

The Wetland Reserve Program was a voluntary program, no longer available, that offered landowners the opportunity to protect, restore, and enhance wetlands on their property. The USDA Natural Resources Conservation Service (NRCS) purchased perpetual easements and provides technical and financial support to help landowners with their wetland restoration efforts through WRP. This program offered landowners an opportunity to establish long-term conservation and wildlife practices and protection. The goal of NRCS is to achieve the greatest wetland functions and values, along with optimum wildlife habitat, on every acre enrolled in the program.

Under the FPE program, the easement area will be restored to the maximum extent practicable to its natural condition and to function as a floodplain. Typical restoration utilizes structural and nonstructural practices to restore the flood storage and flow, erosion control, and improve the practical management of the easement.

Floodplain easements restore, protect, maintain and enhance the functions of floodplains while conserving their natural values such as fish and wildlife habitat, water quality, flood water retention and ground water recharge. Structures, including buildings, within the floodplain easement must be demolished and removed, or relocated outside the 100-year floodplain or dam breach inundation area.

Public Concern: Over the past six years there has been strong local concern and opposition to the WRP and FPE restoration activities within the study area. Concerns have been expressed by the neighboring property owners south of the NRCS easement area that the completed and planned restoration activities have created difficult farming conditions. There are three areas of concern that have been communicated to NRCS as shown on figure 2. Site 1 is the proposed tide gate replacement. Site 2 is the FPE easement plantings and Site 3 is the access road to the Hunt club immediately southwest of the FPE.

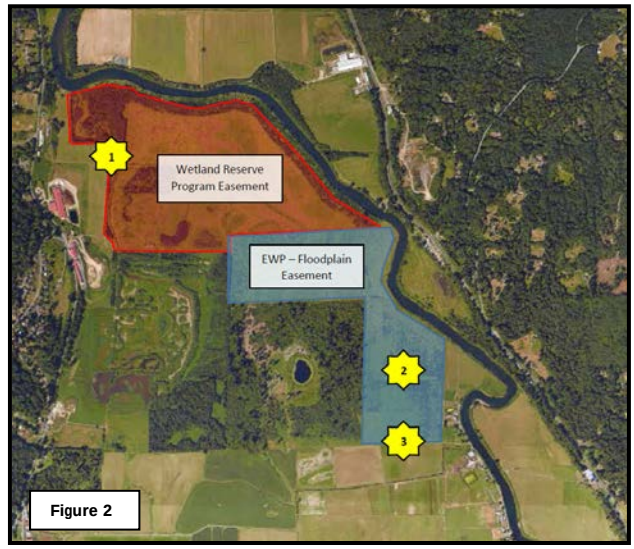

Figure 2

The following is a brief description of the concerns that NRCS has received for each of the sites.

Site 1 (see Figure 2): The proposed project[1] at this location will replace a failing culverts and flap gates that serve to prevent backwater from annual flooding that occurs at the confluence of the Skykomish and Snoqualmie rivers. An integral restoration goal is to replace the existing flap gates with one Muted Tide Regulating (MTR) gate and three side hinged flap gates (Figure 3). The MTR and side hinged gates are beneficial at increasing hydrologic exchange within the wetland area as well as improving the fish passage characteristics of the access road crossing.

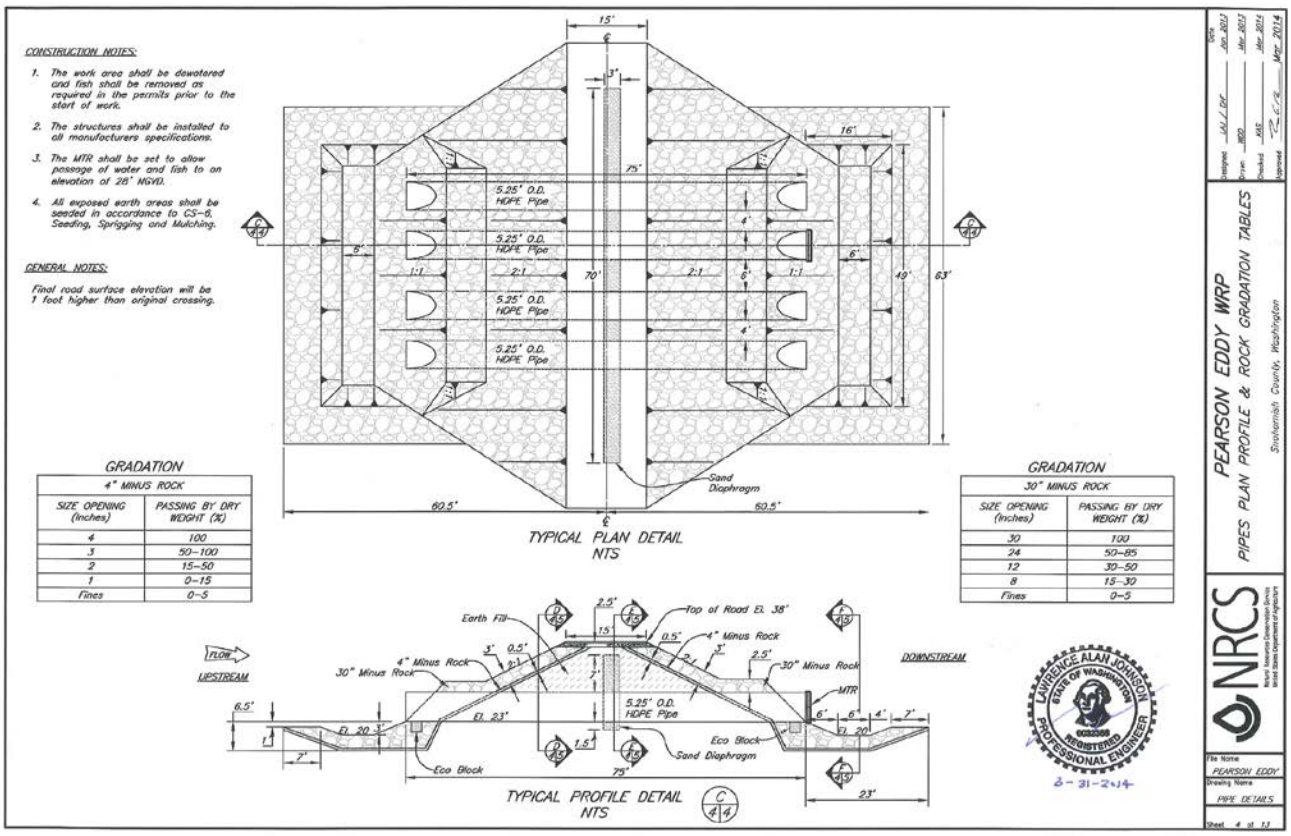

Figure 3. Plan and profile view of proposed culvert replacement at Site 1

The project as proposed will not adversely affect the hydraulic characteristics of the existing crossing. NRCS hydraulic modeling demonstrates[2] that the pre and post construction hydraulic impacts remain unchanged for the modeled flood events.

[1] NRCS Pearson Eddy construction drawings and specifications approved 3-31-2014

[2] Hydraulic Impact Analysis of WRP Project features along Pearson Eddy Slough, dated July 2012

Prior to the NRCS WRP easement acquisition (2004) there was a pumping facility that was utilized to help evacuate flood water from within the northern most floodplain area immediately west of the Snoqualmie River. The pump facility was located at the proposed project location. Evidence of the pump facility can be seen (Photo 1)[3]. After NRCS easement acquisition, use of the pumping facility (Property of the landowner) was no longer needed and was removed from the site by the landowner that sold the WRP easement to NRCS.

Photo 1

The neighboring landowners have made statements that the pumping facility was installed and operated by local farmers, of whom they claim to have been participants. It was used to help drain the farmed lands south of the crossing. They are concerned that the decommissioned pump facility has reduced the drainage characteristics of the overall floodplain area which is within the study area. In addition they are claiming that there is an agreement dating back to 1901 that gives them the legal rights to drainage through a ditch that begins just north of their property and flowed into the Snoqualmie River through Pears Eddy. The USDA Office of the General Counsel regional office in Portland, Oregon has reviewed the information provided by the neighboring landowners and concluded that there is no legal obligation for NRCS to re-install, operate and maintain the pumping facility or to maintain drainage under the 1901 agreement.

NRCS has no records of the pump size or pumping capabilities of the facility. Without relevant pump facility information it is not possible to estimate or model the effects that the pump facility would have had on the evacuation of floodwaters from the study area. It would be anticipated that the abandoned pump facility would serve to accelerate the evacuation of water. However, it is not possible to model the historic pumping system because there is no relevant pump information available. Without this information it is not possible to quantify the benefits of the prior pumping operation.

Site 2 (see Figure 2): The floodplain easement area (Figure 4) was planted into a cottonwood tree complex in 2010. At the time of the plantings, the southern neighboring landowner expressed concern that the trees planted within the easement area would function like a dam during flood events and would back water up on to his land. Upon completion of the planting NRCS continued to receive complaints and concerns that the easement area was creating unacceptable off site impacts. NRCS participated in a public meeting where the local community members expressed their concerns with the easement. Upon conclusion of the meeting with the local community, NRCS agreed to conduct further modeling and to present the results of the hydraulic modeling[4] at another public meeting.

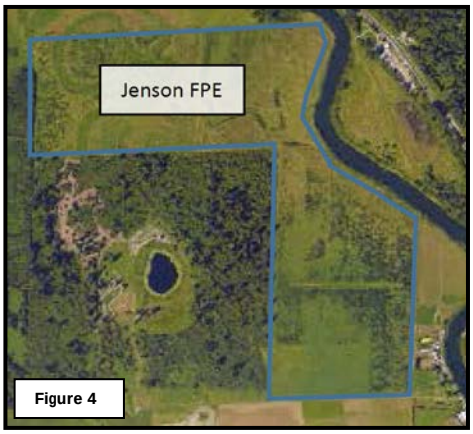

Figure 4

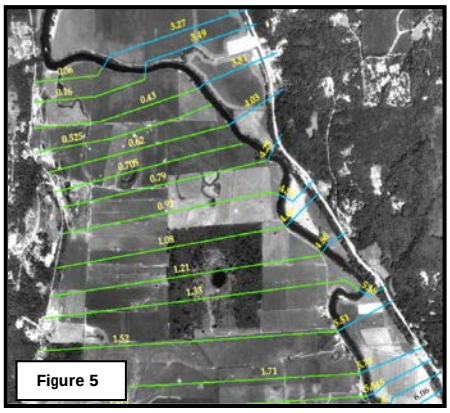
Figure 5

The purpose of the analysis was to determine the effect that the "Full Vegetative Growth" condition would have on the backwater effect of Snoqualmie River floodplain. The study modeled flood events from the Snoqualmie River, large enough to overtop the natural berms. The cross sections of the model (shown in green and blue Figure 5) were adjusted to represent a selected baseline condition and full vegetative growth condition. The baseline condition selected represented the pre-easement condition of the study area. The floodplain roughness factors were increased to represent a mature forested area.

A comparison of the results of the two modeled conditions were

[3] Person's Eddy WRP Hydraulic Analysis; dated March 6th, 2009; Appendix A – Photo Reconnaissance Log

[4] Hydraulic Offsite Impacts Analysis related to the Establishment of Vegetation on the Person Eddy WRP Easement and Jenson FPE dated 5-2-2011.

completed (Table 1) and the results of the analysis demonstrate that the easement plantings, even at the full growth stage have negligible to no effect for the 5, 10, 50, 100, and 500 year runoff events. The cross sections shown in Figure 5 can be matched up with Table 1 to determine the change in depth at specific locations within the study area. Of particular interest is cross section 1.52 (yellow highlight) which is taken nearly along the Snohomish/King County line. The FPE is immediately north of this cross section. From a modeling perspective the backwater increased at most 0.042 feet (½ inch) which for all practical purposes equates to zero rise in the floodwater elevations.

Table 1

Changes in Depth and Velocity between existing agricultural land use base conditions and NRCS project vegetation

		500yr			100yr			50yr			10yr			5yr		
feature	cross section	depth (inch)	depth (feet)	velocity (ft/sec)	depth (inch)	depth (feet)	velocity (ft/sec)	depth (inch)	depth (feet)	velocity (ft/sec)	depth (inch)	depth (feet)	velocity (ft/sec)	depth (inch)	depth (feet)	vel (ft/sec)
floodplain	0.06	0.0	0.00	-0.44	-0.1	-0.01	-0.47	-0.2	-0.02	-0.50	0.0	0.00	-0.43	-0.2	-0.02	-0.52
floodplain	0.79	0.1	0.01	-0.02	0.1	0.01	-0.02	0.2	0.02	-0.02	0.2	0.02	-0.02	0.1	0.01	-0.02
floodplain	1.52	0.4	0.03	0.00	0.4	0.03	0.00	0.5	0.04	0.00	0.4	0.03	0.00	0.5	0.04	-0.01
floodplain	1.92	0.4	0.03	-0.01	0.4	0.03	0.00	0.5	0.04	0.00	0.4	0.03	0.00	0.5	0.04	0.00
floodplain	2.99	0.4	0.03	-0.01	0.4	0.03	0.00	0.5	0.04	-0.01	0.4	0.03	0.00	0.4	0.03	0.00
floodplain	3.95	0.2	0.02	-0.01	0.4	0.03	-0.02	0.5	0.04	-0.02	0.4	0.03	-0.01	0.2	0.02	-0.02
floodplain	4.80	0.2	0.02	0.00	0.2	0.02	0.00	0.4	0.03	-0.01	0.2	0.02	0.00	0.1	0.01	0.00
Snoqualmie	4.28	0.1	0.01	0.14	0.1	0.01	0.23	0.1	0.01	0.23	0.1	0.01	0.20	0.1	0.01	0.21
Snoqualmie	5.51	0.4	0.03	0.01	0.4	0.03	0.02	0.5	0.04	0.01	0.4	0.03	0.02	0.4	0.03	0.01
Snoqualmie	6.91	0.2	0.02	0.00	0.4	0.03	-0.01	0.5	0.04	-0.01	0.5	0.04	0.00	0.5	0.04	-0.01
Snoqualmie	9.75	0.2	0.02	0.00	0.2	0.02	-0.01	0.4	0.03	-0.01	0.2	0.02	-0.01	0.1	0.01	-0.02
Snoqualmie	11.27	0.2	0.02	0.00	0.2	0.02	-0.01	0.2	0.02	0.00	0.2	0.02	0.00	0.1	0.01	0.00

A second public meeting was held and NRCS presented the results of the modeling effort. Dan Moore, P.E., Hydraulic Engineer and modeler presented the findings and responded to questions from the meeting attendees. The attendees provided many comments and anecdotes of the study area flooding. By the end of the meeting, many of the attendees were not convinced that the hydraulic modeling accurately represented the study area.

NRCS was satisfied that the hydraulic modeling fairly represented the study area and that the comments received at the public meeting did not necessitate the need to revise the analysis. As such, the additional technical work fulfilled our public obligations to communicate the likely effects of the two easement areas. Since there were no negative impacts of the modeled future condition NRCS considered the local neighbor concerns as addressed.

Site 3 (see Figure 2): The neighboring landowner immediately south of the FPE has expressed repeated concerns about surface water draining south over an access road and onto his farm field. Claims were made that the surface water is rendering a portion of his farmland as unusable.

NRCS has visited the site a number of times to assess the situation. At the time of our site visits, there was evidence of water flow over the roadway onto the farmland in question. There is a network of drainage ditches, pipelines and flap gates that were used in the past to provide drainage for the farmland areas that are now under NRCS easements. The condition of many of the drainage features are run down and non-functional. If drainage is to be maintained, rehabilitation work will be needed.

Surface Drainage Modeling Background: NRCS initiated a modeling effort[5] to evaluate the effectiveness of the drainage features contained within the study area. The availability of new data for the study area called LiDAR provided the opportunity to analyze the study area more effectively by conducting a two-dimensional analysis utilizing the U.S. Amy Corp of Engineers HEC program, HEC-RAS. LiDAR data provides accurate topographical information that can be incorporated into the modeling software. The results of the modeling are a dependable representation of the inundation depths throughout the study area based on a set of predefined modeling assumptions regarding the hydrologic inputs into the model.

[5] Addendum to the Hydraulic Impact Analysis of WRP Project features along Pearson Eddy Slough, date November 2015

Key hydraulic features were either programmed or topographically established as part of the HEC-RAS model. Figure 6 illustrates the hydraulic controls and existing drainage features within the study area. The LiDAR data was utilized to establish the topographical hydraulic features within the model study area. The LiDAR data set represents the "Bare Earth" ground surface which provides an excellent representation of the topography of the study area. All topographical features; roads, ditch locations, berms and ground features are accurately represented by the LiDAR data set. Since LiDAR does not record elevations below the water surface, the terrain model was edited to estimate the drain ditch capacities. The identified hydraulic controls determined the rate that the flood water exits the floodplain. The flood control gates that were installed prior to NRCS easement acquisitions were utilized and needed by the local farmers to effectively drain their lands of water for farm field access and farming production purposes. The following describes the current condition and functionality of each identified hydraulic control.

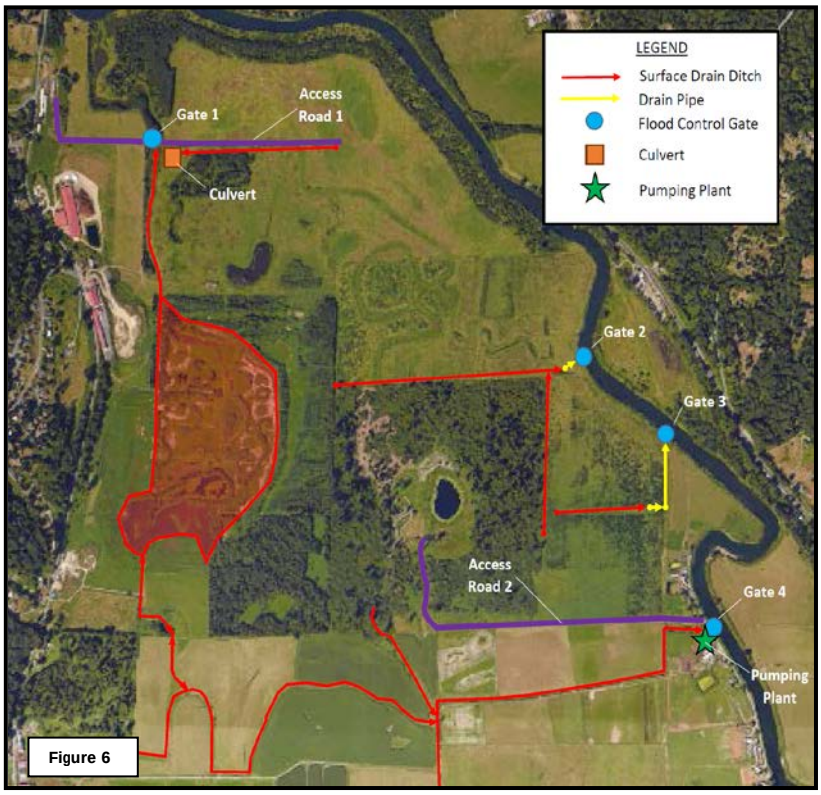

Figure 6

Gate 1 (see Figure 6): There are four culverts with flap gates through the associated access road at this location. The structure serves two purposes. First, it prevents flood water from the Snoqualmie River from backing up onto the WRP easement, private and farmland. Secondly, it is the sole legal access point into the NRCS WRP easement area.

Infrastructure at this site is in a state of disrepair. Flood events over the past few years have begun to cause significant erosion of the earth fill on the upstream face of the crossing. The embankment is vertical and unstable and there is no vegetative cover. The most recent flooding during November 2015 has caused embankment erosion to continue. It is likely that the embankment will likely fail soon with sustained and/or frequent flooding.

Photo 2

A flap gate was recently reattached on the downstream side of the crossing, Photo 2 shows the missing flap gate. The flap gates prevent water from backing up onto the farmland upstream of the access road crossing. Reattachment of the flap gate was essential to ensure that the upstream land was not negatively impacted by backwater flooding through the structure due to the missing gate.

As previously described there was a pumping facility at this location. NRCS has no records of the pump size or pumping capabilities of the historic pumping facility. The pump can be observed in Photo 1, however the pump house and motor were no longer present when the photo was taken.

Culvert (see Figure 6): The culvert identified in Photo 3 allows surface water from the drainage ditch to exit into the main channel immediately upstream of the Gate 1 structure. The culvert allows water to flow unobstructed in either direction. The culvert is estimated to be 48 inches in diameter. The pump in the photo is no longer present. It was removed when NRCS acquired the easement.

Photo 3

The culvert is a critical drainage feature within the study area. The free flow of water is necessary in order to facilitate drainage from the WRP and FPE easement areas. It is important to maintain this feature and to remove trash or other debris that could prevent the structure from allowing the free flow of water.

Access Road 1 (see Figure 6): The access road is the sole legal access point into the NRCS WRP easement area. It is intended to be maintained for light vehicle use such as ATV's and pickup trucks for the purpose of conducting maintenance activities within the easement area. Approximately 50 feet east of the Gate 1 structure, there is erosion upstream and downstream of the access road. At this location the erosion is more pronounced on the north side of the road. It does appear that erosion is occurring south of the road. There is a section approximately 75 feet that has not eroded yet. If the erosion continues, it is possible that the channel will bypass the gate structure at this location for some or all flood events. Once the channel has formed, flood water from the Snoqualmie River would also be able to back up through the channel and enter the area upstream of the access road. NRCS has not planned corrective actions for the erosion at this time.

Gate 2 (see Figure 6): The flap gate and buried drain pipe at this location carry surface water from two drain ditches to the Snoqualmie River. The two drain ditches, buried drain pipe and flap gate are in poor functional condition. The two drain ditches have not been maintained by the landowner for many years. As such the ditches are overgrown with Canary Reed Grass and there have been unauthorized modifications to one of the drain ditches. The drain ditch that runs south to north was filled in at the outlet with soil sometime during the past three years. This has prevented surface water from leaving the area served by the drain.

The buried drain pipe and tide gate are presumably in poor operation. The drain ditch water enters the drain pipe through what appears to be a vertical hole in the ground and then enters into the pipe. The buried drain pipe is approximately 18 inches in diameter based on visual observations. There is erosion that has occurred from water entering the pipe at this location. In addition, NRCS employees have visually observed that the buried pipe connected to the flap gate is heavily corroded. At this time it is not known if the flap gate is functional or even present. The buried drain pipe and flap gate are located on private land outside the NRCS easements.

Gate 3 (see Figure 6): Similar to Gate 2, the flap gate and buried drain pipe at this location carry surface water from a drain ditch into the Snoqualmie River. The drain ditch, buried drain pipe and flap gate are in poor functional condition. The drain ditch has not been maintained by the landowner for many years. The ditch was installed to provide an outlet for the tile drains installed to drain the surrounding farmland. The drain ditch is overgrown with Canary Reed Grass. The buried drain pipe and tide gate are presumably in poor operation. The drain ditch water enters the drain pipe through a small water control structure. The diameter of the buried drain pipe is unknown. NRCS employees have attempted to locate the tide gate but, have been unable to locate it due to the steep river bank and vegetative cover. It is not known if the flap gate is functional or even present. The buried drain pipe and flap gate are located on private land outside the NRCS easements.

Gate 4 (see Figure 6): This structure serves multiple purposes. It provides an outlet for the drainage ditch immediately west and south of the structure. The flap gates prevent flood water from backing up onto the farmland surrounding the drain ditch. A county road crosses over the structure and provides access to the northern properties north of the structure. Observations would indicate that all of the structural features of the crossing and the drain ditch are in serviceable condition.

The drainage network that delivers surface water to Gate 4 has a significant effect on how water evacuates the farmland. Generally, as flood water recedes it leaves the floodplain impoundment area through Gates 1 and 4. At some point during the draining process the water south of the Snohomish/King county line along Access Road 2 drains solely toward the Gate 4 structure. NRCS staff have not inventoried the drainage network so it is not known what the operational condition of the drainage system is. It is also unknown what other hydraulic controls exist. There may be culverts and other similar water control structures that could impeded surface water drainage of this area.

Pumping Plant (see Figure 6): The pumping facility had been used to help evacuate floodwater from the floodplain area served by the Gate 4 structure and is not located on the NRCS easements. Currently, the pumping plant is non-functional. The pump and the motor are not present in the pump house as shown in Photo 4. Access by NRCS staff to view this pumping station was granted by a representative of the neighboring landowner since the landowner could not be present the day of the site visit.

Photo 4

The previous pump and motor specifications are unknown. It is not possible to calculate the effect that the pump station would have on evacuating impounded water from the area drained into the Snoqualmie River. It would be anticipated that the pumping station would provide the greatest benefit, albeit small, as the flood levels on the falling side of the hydrograph after the water from the Snoqualmie River becomes disconnected from the floodplain.

Based on visual observation, the pumping facility could be rehabilitated to a fully functional condition. Installation of a pump, motor and associated wiring should bring the pumping facility back into full operation.

Access Road 2 (see Figure 6): This road provides access to the Heckman Gun Club hunting area, farm fields to the south and to the NRCS Floodplain Easement immediately north of the road. The road is regularly utilized by members of the Club. It is maintained to provide access throughout the hunting season. As previously stated, there is evidence of surface water flowing south over the roadway from the FPE onto the farmland. There is light surface erosion occurring at low points along the access road over an estimated 200 to 500 feet length.

The drainage ditches that deliver surface water to Gate 2 and Gate 3, and the gate structures are in various states of disrepair. The decreased functionality of the flap gates, buried pipeline and the drain ditches are likely causing water to flow over the access road for some rainfall/flood events. The likelihood of water flowing over the access road increases immediately following a flood where the floodplain is inundated. In this situation, additional rainfall may result in water flowing over Access Road 2 onto the farmland to the south as the water slowly recedes evacuating the floodplain through Gate 1 and Gate 4.

<u>Surface Drainage Modeling Assumptions:</u> In order to set up the model to represent the existing site, it was necessary to establish the functionality of each hydraulic feature within the HEC-RAS model. The following is how each was accounted for in the modeling effort.

Gate 1: The four 60 inch diameter culverts as planned[6] were modeled. The existing culverts currently in place are one 48 inch and three 60 inches in diameter. Since the proposed project at this location

[6] NRCS Pearson Eddy construction drawings and specifications approved 3-31-2014

replaces the existing culverts with culverts having a slightly larger conveyance capacity, the hydraulic response will be slightly improved over the existing condition.

Gate 2: It was assumed that this outlet and flap gate are not present since the functionality is unknown.

Gate 3: It was assumed that this outlet and flap gate are not present since the functionality is unknown.

Gate 4: The pipe and gate were included and programed into the model. Estimates were made regarding the pipe diameter, length and the total number of pipes. In addition it was assumed that the structure was fully functional.

Access Road 1: The access road was not revised.

Access Road 2: The access road was not revised.

Pump Plant: The pumping plant was not included in the analysis. Additional information regarding pump model and motor size would be needed to model the effect that the pumping plant would have on the evacuation of water from the study area.

Culvert: It was assumed that the culvert was not present.

LiDAR: the LiDAR data set was assumed to accurately represent to the topographical features of the study area.

Snoqualmie River Stage: For the "Just Drain" scenario, the river stage was set as to not create backwater effect at any of the gate outlets. The gates were allowed to gravity flow freely out to the river. The 24 hour five-year rainfall event scenario was set to coincide with a typical event on the Snoqualmie River, which caused the flap gates to be closed during part of the simulation.

Surface Drainage Modeling Results: The completed drainage model and resulting outputs provide a representation of how water flows throughout the study area. The model outputs allow for an in-depth look at the effects that micro-hydrology and hydraulics have on and off of the easements.

Two hydrologic drainage scenarios were evaluated[7]. First, a five-year storm event was modeled with incoming flow from upstream in addition to accounting for rainfall on the entire area. A second flood scenario started with a high stage of standing water across the area, with no additional inflow, and analyzed how long it would take to drain. At the micro scale of the terrain, the presence of the hydraulic controls govern where the water exits the study area. Since the primary goal of this report is to evaluate the day to day drainage characteristics of the study area, it is not necessary to characterize the two studies. The day to day drainage characteristics will be very similar if not the same between the two scenarios. It was decided to present the model outputs for the five year storm event.

The results presented are from the five-year local storm event that was modeled. Incoming flow from upstream (flowing from south to north) in addition to accounting for rainfall on the entire area were input into the model. This modeling scenario was run over a 14 day period of time. Over the course of the rainfall event the model predicts the flow direction, depths and velocities of surface water throughout the study area. While the illustrations showing the ponding do not have depth or elevational information presented, they do depict the areas of ponding throughout the study area. The depth of the ponded water increases as the color changes from light to dark blue. It should be noted that at all times the flow velocities are quite low, below 1 foot per second outside of the ditches, which supports the bathtub characterization.

On day 1 at midnight (Figure 7) the study area inundation is at the maximum depth. Drainage channels are depicted as narrow blue lines whereas the ponded areas are depicted as large blue areas. As the water drains from the study area, pockets of isolated surface water are evident. Once a low area is no longer hydraulically connected to a channel or another body of water it remains static. Since evaporation and infiltration are not variables in the model, the water will be ponded indefinitely in the model results.

On day 8 at noon (Figure 8) there is still much surface water present draining from the study area, however there are now many isolated pockets of water in depressions and drain ditches. The majority of the water that was able to evacuate the site by this time. The remaining water will drain very slowly toward Gates 1 and 4 if

[7] Addendum to the Hydraulic Impact Analysis of WRP Project features along Pearson Eddy Slough report dated November 2015

the water is hydraulically connected to channels and/or depressions leading to the outlets. If they are not, drainage will no longer occur from isolated pockets of standing water.

On day 14 at noon (Figure 9) there is very little change in ponded surface water from figure 8. Water level from the Snoqualmie is preventing drainage from the study area. The area will not drain until after the water level in the Snoqualmie River lowers. The remaining water within the study area that is hydraulically connected and able to drain to Gate 1 and 4 drains slowly and will completely drain only after the Snoqualmie River water lowers. The slow drainage rate is also due to the limited hydraulic connectivity and low hydraulic head.

Conclusions and Recommendations: The most recent 2D model results confirm earlier model findings that the WRP vegetation has no effect on drainage. The micro-topography study results are similar in that the slow moving drainage is not impeded by the vegetation. Surface drainage occurs slowly throughout the study area. Gate 1 and 4 are the only outlets that allow impounded floodwater to exit the site. While the two gates provide a hydraulically connected outlet when the floodplain area is inundated, the positive effect is diminished as the water recedes.

The micro-hydraulics of the study area becomes a significant factor as the flood water recedes. Stranded surface water is located in disconnected low areas and drainage ditches, these pockets of water cannot drain from the site. At this stage, the stranded areas of surface water will leave the site through infiltration, evaporation or transpiration. These mechanisms were not captured in the modeling effort, therefore it is not possible to predict how long standing water would remain on site following flood events.

Historically the pumping plants served to accelerate the evacuation of flood water within the study area. There was a pumping facility located at the Gate 1 structure location, and there is a non-operational (unknown if functioning at this time) pump facility located at the Gate 4 structure. Without pertinent pump or motor information it is not possible to model the effect that the pumping facilities would have on the evacuation of water from the study area. It should be anticipated that there would be a positive benefit, however it is not possible to speculate on the reduced number of days that the study area would be inundated.

Surface drainage of the study area could be improved by rehabilitating and maintaining the existing drainage ditch network. Identification of the low areas where water can pond and ensuring that they are hydraulically connected to drainage features would help to remove water from the desired areas throughout the study area. For example, Gates 2 and 3 provide drainage to the entire FPE easement. The modeling demonstrates the importance that the drainage ditches, buried pipeline and flap gates have on the easement. Currently as modeled, standing water from the drain ditches and the land they serve are ponded and are hydraulically disconnected from the Gate 1 and 4 structures. Re-establishment of Gates 2 and 3 would allow water from the disconnected area within the FPE to drain from the site. Generally, drainage maintenance and the associated costs are the responsibility of the landowner and not NRCS.

Pumping plants may provide beneficial accelerated evacuation of water from the study area. Before pursuing the re-establishment or new pumping facilities, it is recommended to model the effects to determine the effectiveness of alternatives. An economic analysis should be completed for the alternatives in order to evaluate the benefits vs. cost. A high operating cost may negate the economic benefits of installing and operating a pump facility.

Re-establishment of the pumping facility that once was located on the WRP easement could be authorized by NRCS through a compatible use agreement. All installation and maintenance costs would be burdened by a local entity/sponsor and not NRCS. The Pumping Plant (see Figure 6) rehabilitation, operation and maintenance cost of would be burdened by a local entity/sponsor and not NRCS.

Figure 7: Model Results – Day 1 at Midnight

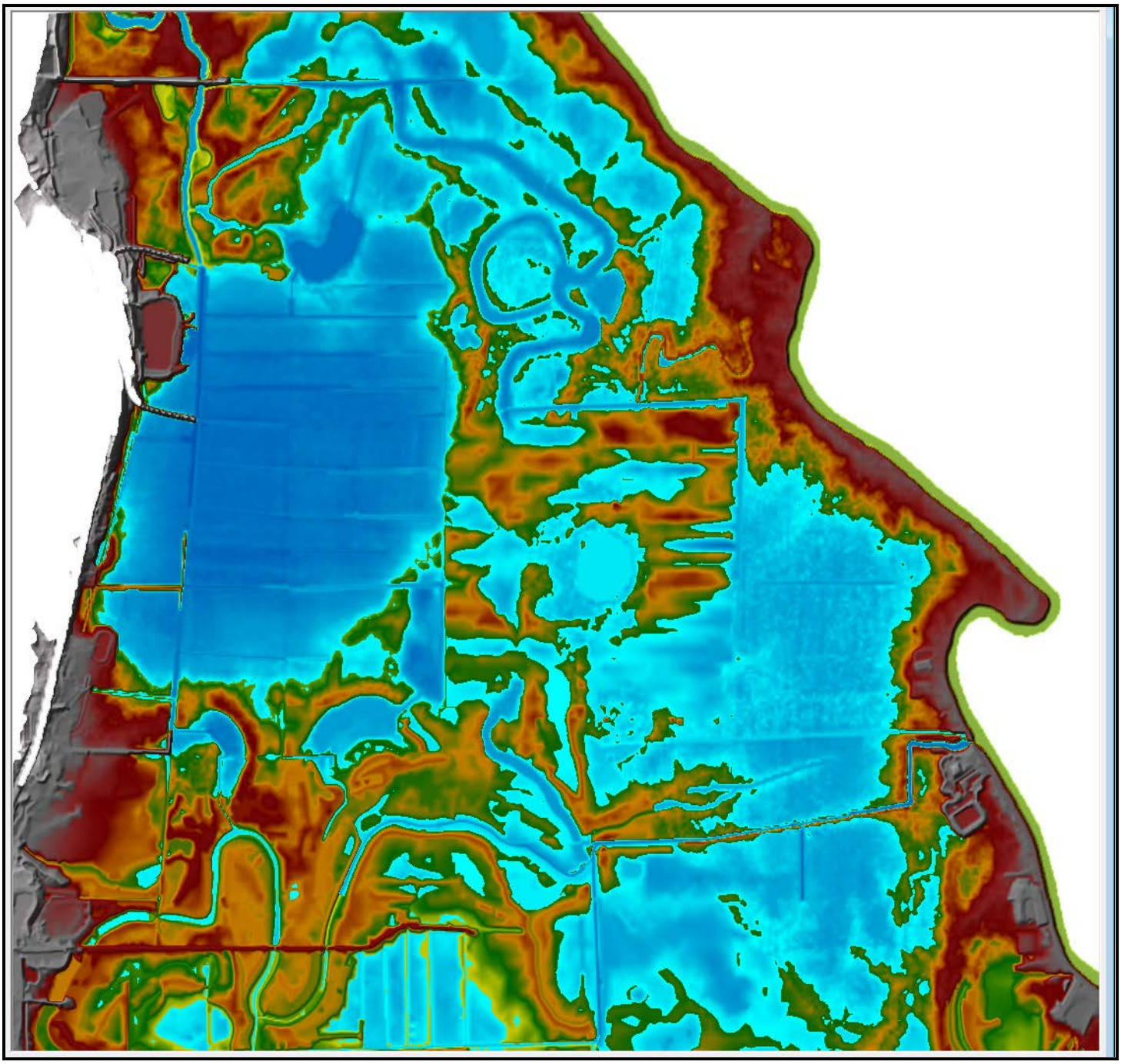

Figure 8: Model Results – Day 8 at Noon

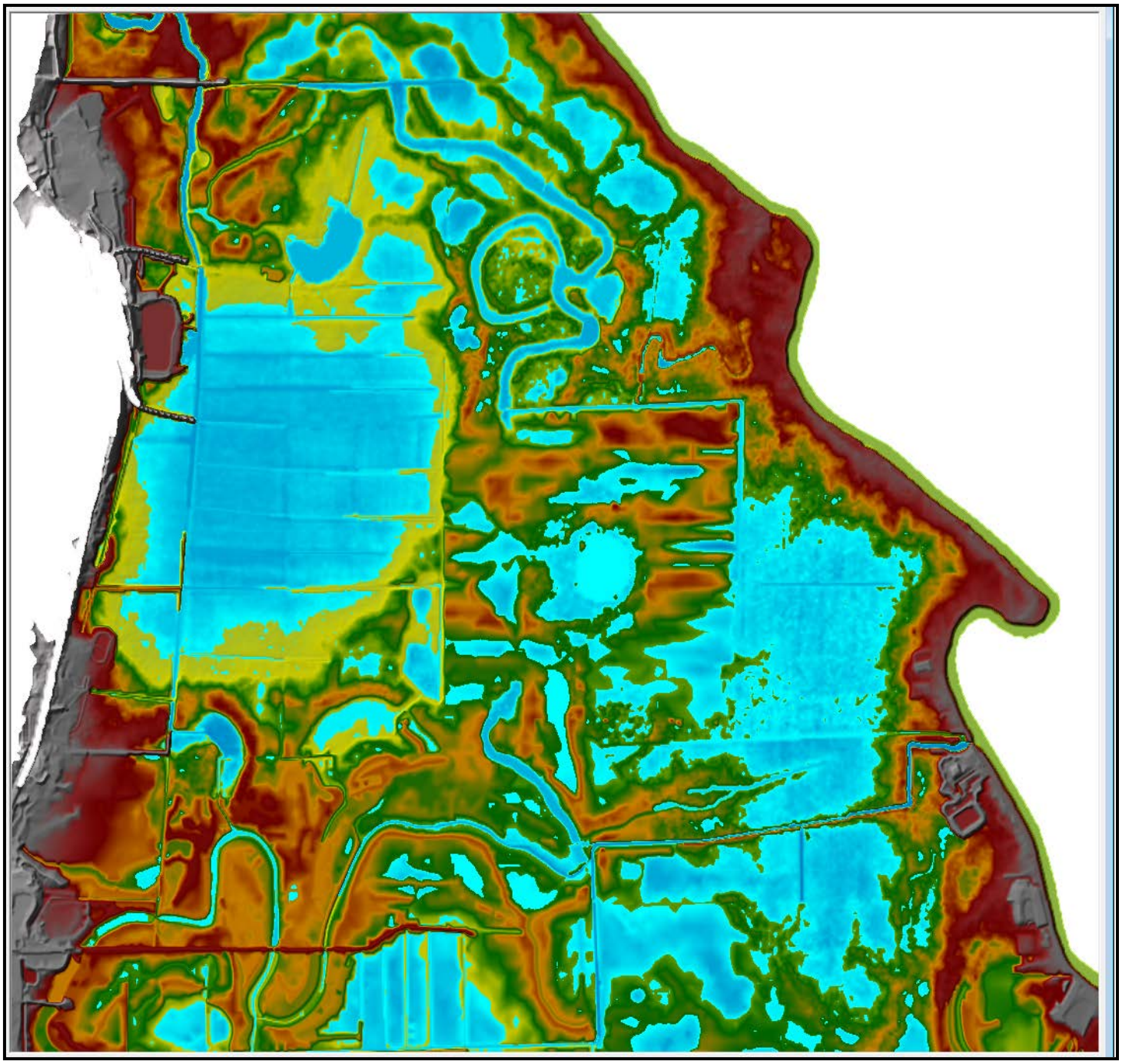
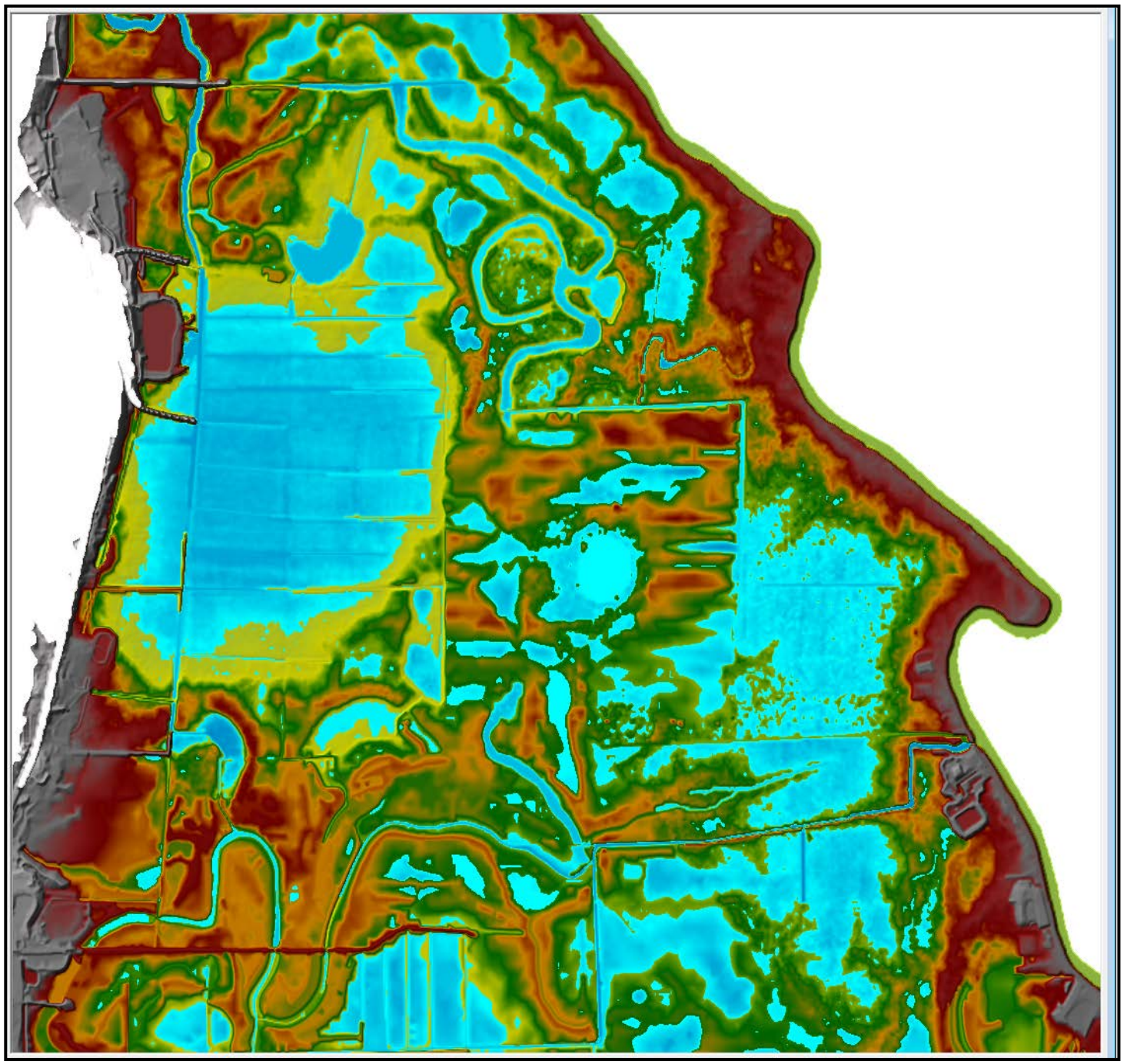
Figure 9: Model Results – Day 14 at Noon