INTRODUCTION

As part of the Lake Jesup 1135 study a RMA2 model was developed. RMA2 is a two-dimensional depth averaged finite element hydrodynamic numerical model. It computes water surface elevations and horizontal velocity components for sub-critical, free-surface two-dimensional flow fields. The RMA2 model was developed to be used for comparing potential alternatives; it is not a predictive model.

Previous studies have been performed on the Lake Jesup area, a three-dimensional Environmental Fluid Dynamics Code (EFDC) model was prepared by Scientific Environmental Applications, Inc. for the St. Johns River Water Management District (SJRWMD) in December 1998. The bathymetry for this model originated from surveys performed by the SJRWMD.

The EFDC model focused mainly on the circulation within Lake Jesup with inflow boundaries at Soldier/Gee Creek, Howell Creek, and Black Hammock; an outflow boundary was set at the State Route 46 Bridge USGS gage station. Due to the proximity of the boundary conditions there is forced flow through Lake Jesup.

The RMA2 model was developed to focus on the braided channels at the mouth of Lake Jesup and ensure there is no forced flow through Lake Jesup. The model also allows for analysis of the change in flow patterns through the braided channels for each alternative, including changes made to Government Cut. In addition to developing the RMA2 model, a review of gage data was performed to gain an understanding of the observed daily flow reversals at the mouth of Lake Jesup is influenced by wind.

One restriction to the project design is the St. Johns River is authorized as a federal navigation channel to the downstream mouth of Lake Harney; because of this there must be a navigation channel of a minimum of 100’ width and 5’ depth connecting Lakes Monroe and Harney.

REVIEW OF GAGE DATA

Prior to modeling, a review of gage data was conducted at the following locations: stage at Black Hammock, stage and flow at the southern edge of (above) Lake Harney, flow at the SR 46 bridge at the mouth of Lake Jesup (referred to as “outlet”), and the stage at the northern edge of (below) Lake Monroe. In addition to the flows and stages, wind speed and direction from the Sanford Airport were reviewed to determine if the stages and flows are impacted by wind. Data from 22 March 1997 through 17 September 1997 was reviewed, this time period was selected due to the concurrency of data available at the various gages in the region. Figure 1 shows the locations of the gages used in the comparison.

The flows at the SR 46 Bridge gage oscillate near zero showing an inflow and outflow at this location, therefore the assumption of a constant outflow cannot be made. Flow from Lake Harney during the review period does not oscillate, flows leaving the lake travel north towards Lake Jesup due to the head differential. The gage at the downstream outlet of Lake Monroe shows some oscillations of flow around zero, but the general trend of the data is in a downstream direction.

There is a noticeable daily pattern to wind speed, the speed increases throughout the day and decreases with nightfall. The wind speed and direction correlate to stage and flow in Lakes Jesup and Monroe. During high wind speeds from the northwest, the water in Lake Monroe tends to flow towards the southeast side of the lake causing the stages at the gage to drop and flows to go in an upstream direction. This wind effect can also be seen at the outlet to Lake Jesup. Lake Harney does not experience the same affects from wind speed likely due to the head differential from Lake Harney to the marsh area.

In summary, the gage data shows water movement at the mouth of Lake Jesup is predominately wind driven with a distinct seiche, or sloshing back and forth, between Lakes Monroe and Jesup. The wind does not create a seiche between Lake Harney and Lake Jesup due to the change in elevation between Lake Harney and the braided channels near the mouth of Lake Jesup. Figure 2 shows the correlation of wind speed and flows for Lakes Monroe, Jesup and Harney. Figure 3 shows wind speed and stages for the model run time period. Please note, “Outlet” is referring to the gage at SR 46 Bridge, the mouth of Lake Jesup.

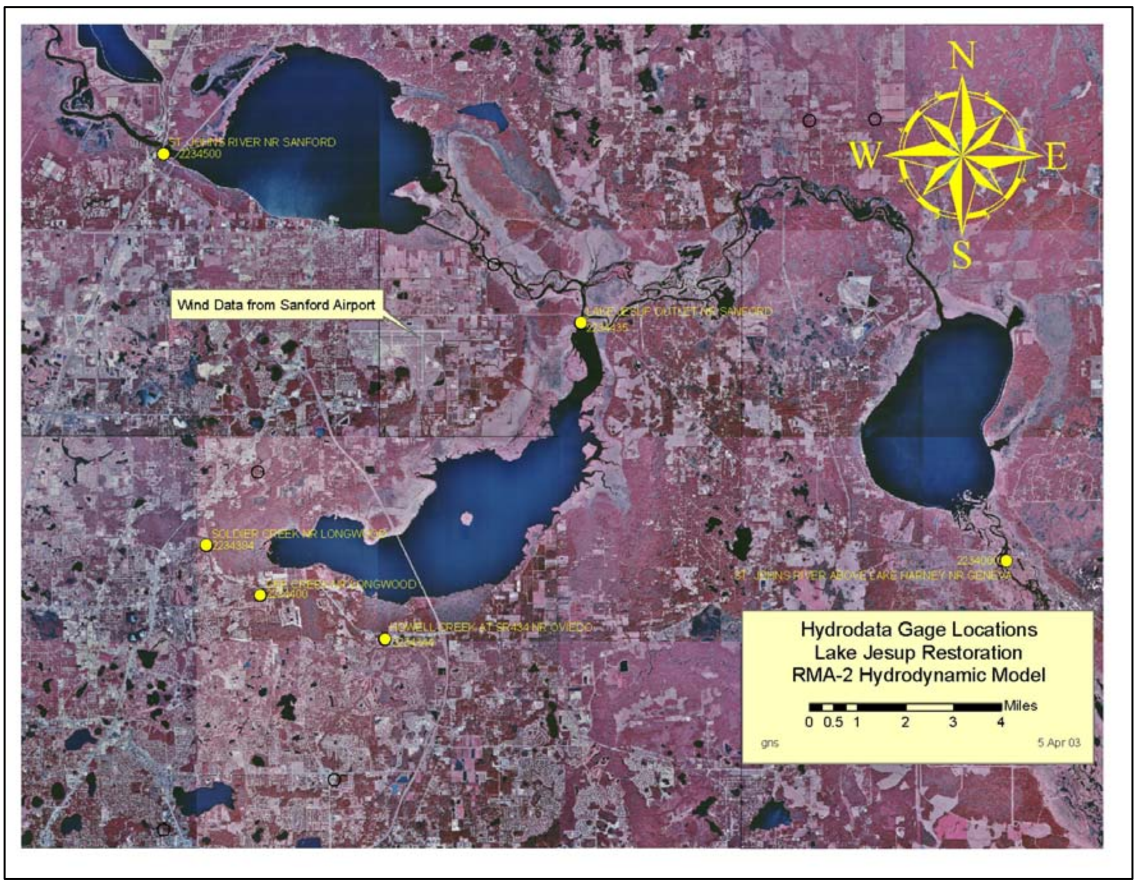

Figure 1. Locations of gages used in comparison study.

Figure 2. Gage Data Comparison Wind Speed with Lake Outlet Flows

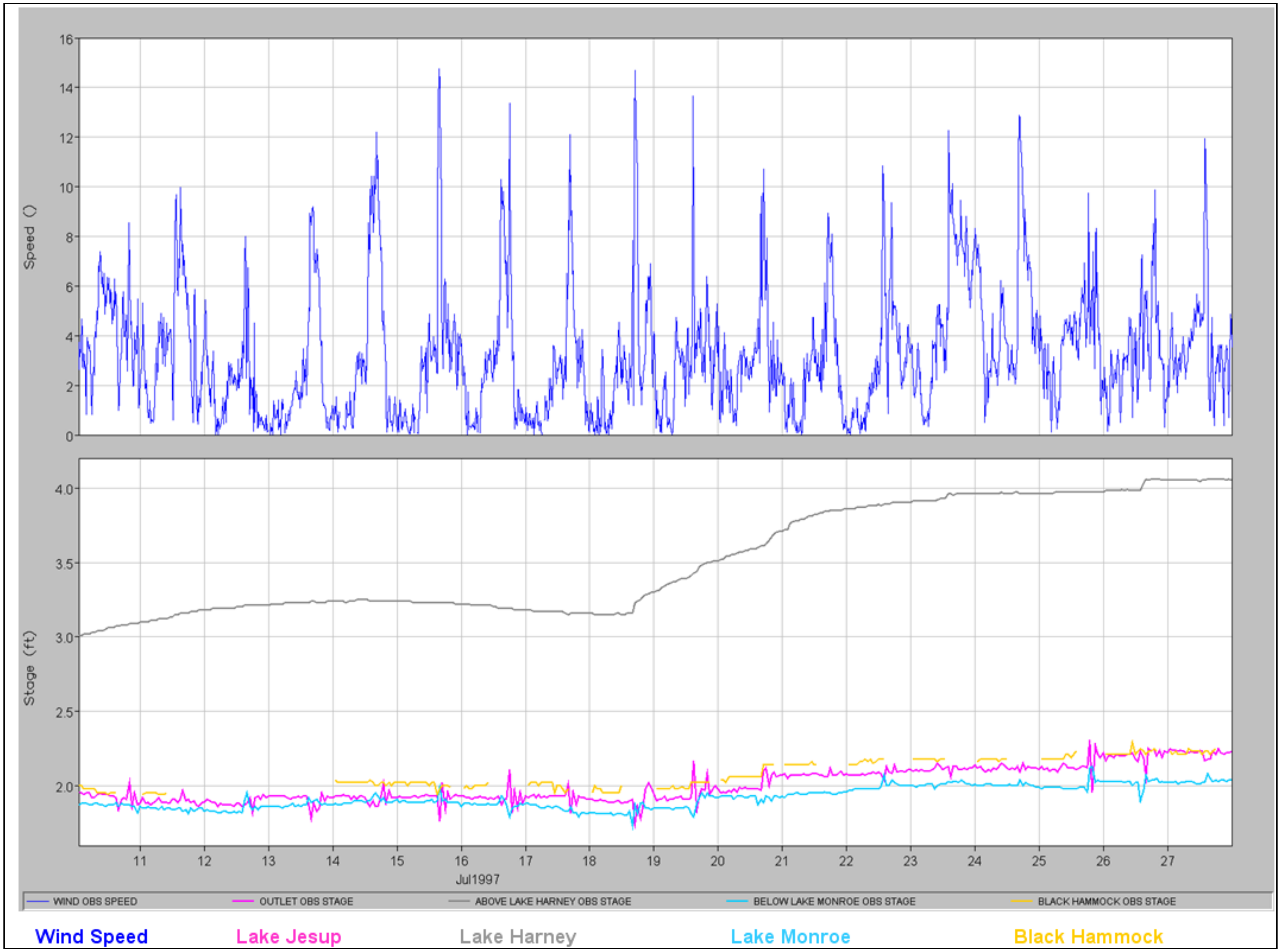

Figure 3. Gage Data Comparison Wind Speeds with Lake Stages

RMA2 MODEL

The RMA2 model is made up of the geometry component and boundary conditions. The geometry data is referred to as the mesh, this mesh is developed from bathymetry data. The bathymetry data used for this project originated from various data sources. Lake Jesup bathymetry is the same as that used in the Environmental Fluid Dynamics Code (EFCD) model prepared by Scientific Environmental Applications, Inc. for the St. Johns River Water Management District in December 1998. The US Army Corps of Engineers condition survey performed in June 2001 was used for the centerline of the St. Johns River between Lakes Monroe and Harney. The 1939 bathymetry survey was used for the braided streams that lie within the marshy area. Data for the connection immediately north of Government Cut was gathered using a GPS unit in March 2003. Florida Department of Transportation provided survey information in the vicinity of the SR 46 Bridge.

The boundary conditions were set at gage stations at the upstream side of Lake Harney and the downstream side of Lake Monroe. These locations ensure the boundary conditions are significantly removed from the project area and will not interfere with the results. Also, the oscillations in the flows at the gage on SR 46 Bridge demonstrate the need for boundary conditions to be significantly removed from the project area for proper representation. Inflows to the model are located in three locations along Lake Jesup, Black Hammock, Howell Creek, and Soldier/Gee Creek.

The model was run to simulate four days of gage data, 11 July 1997 through 14 July 1997. There are two flow peaks during this time with moderate stages for use in calibration of the model. The RMA2 model was calibrated to flow and stage with the primary focus on matching flows as closely as possible within budget and time constraints.

ALTERNATIVE PLAN DESCRIPTIONS

Several alternatives were modeled to establish possible benefits. Figure 4 shows an aerial view of the project area with various channels labeled, Channel C is shown in an approximate location. The project alternatives varied based upon which channels were opened and which were allowed to remain closed. Channel A remains open for all alternatives. Table 1 shows the various alternatives modeled for analysis. The Government Cut restriction refers to constructing a navigable weir across Government Cut which would restrict flow yet continue to allow navigation.

Table 1. Lake Jesup Restoration Alternative Plans

Alternative	Chan A	Chan B	Chan C	Gvt Cut	Gvt Restricted
Existing	Open	Closed	Closed	Open	No
Plan 1	Open	Open	Open	Closed	N/A
Plan 2	Open	Open	Closed	Closed	N/A
Plan 3a	Open	Open	Open	Open	No
Plan 3b	Open	Open	Open	Open	Yes
Plan 4a	Open	Open	Closed	Open	No
Plan 4 b	Open	Open	Closed	Open	Yes
Plan 5	Open	Closed	Open	Closed	N/A

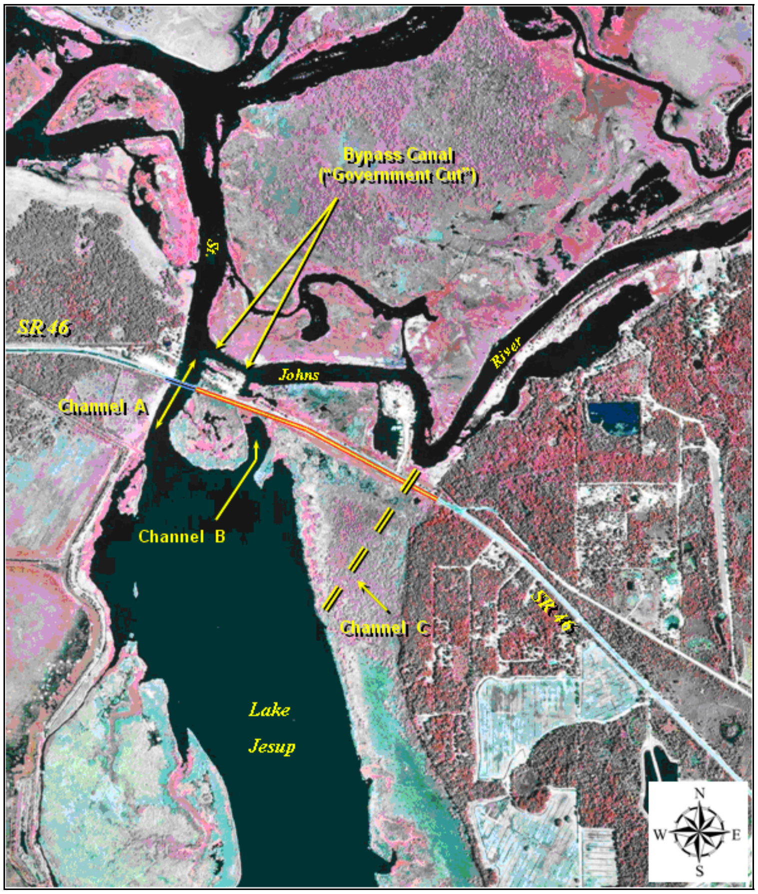

Figure 4. Lake Jesup Project Area Aerial

MODEL RESULTS

To accurately compare model results, flux lines were placed in areas of interest. These lines ensured the data was being compared at the same location for each alternative. Figures 5 and 6 show the location of the model boundary and flux lines 5 used in the model. The reasoning behind the location of the majority of the flux lines is fairly straightforward with the possible exception of Line 7. Line 7 was placed in the connection immediately to the north of Government Cut to ensure an accurate representation of the distribution of flow if Government Cut is closed or restricted.

The total flow through Channels A, B, and C into and out of Lake Jesup were analyzed. Plan 5 (Channels A and C open, Channel B and Government Cut closed) provides the greatest total flow (absolute value). Existing conditions experiences a total flow of approximately 7275 cfs, Plan 5 increases the total flow to approximately 16875 cfs, Plan 1 increases the total flow to approximately14219 cfs, and Plan 2 increases the flow to 13266 cfs. To reach this total flow amount, the flow across Line 3 was used for existing conditions and Lines 3, 12, and 19 were summed for Plan 1 and Plan 5; and Lines 3 and 12 were summed for Plan 2. Line 3 represents flow through Channel A, Line 12 is used to represent the flow through Channel B, and Line 19 represents flow through Channel C. Table 2 shows the total flows through each channel for each alternative.

Table 2. Flows In/Out of Lake Jesup through Channels A, B, and C

		Plan							
		Existing	Plan 1	Plan 2	Plan 3a	Plan 3b	Plan 4a	Plan 4b	Plan 5
Flow	Channel A	7275	7563	7449	4115	4418	4663	4870	7434
	Channel B	0	3380	5817	2130	3250	3250	3268	3699
	Channel C	0	3276	0	3258	3259	0	0	5742
Total Flows		7275	14219	13266	9503	10927	7913	8138	16875

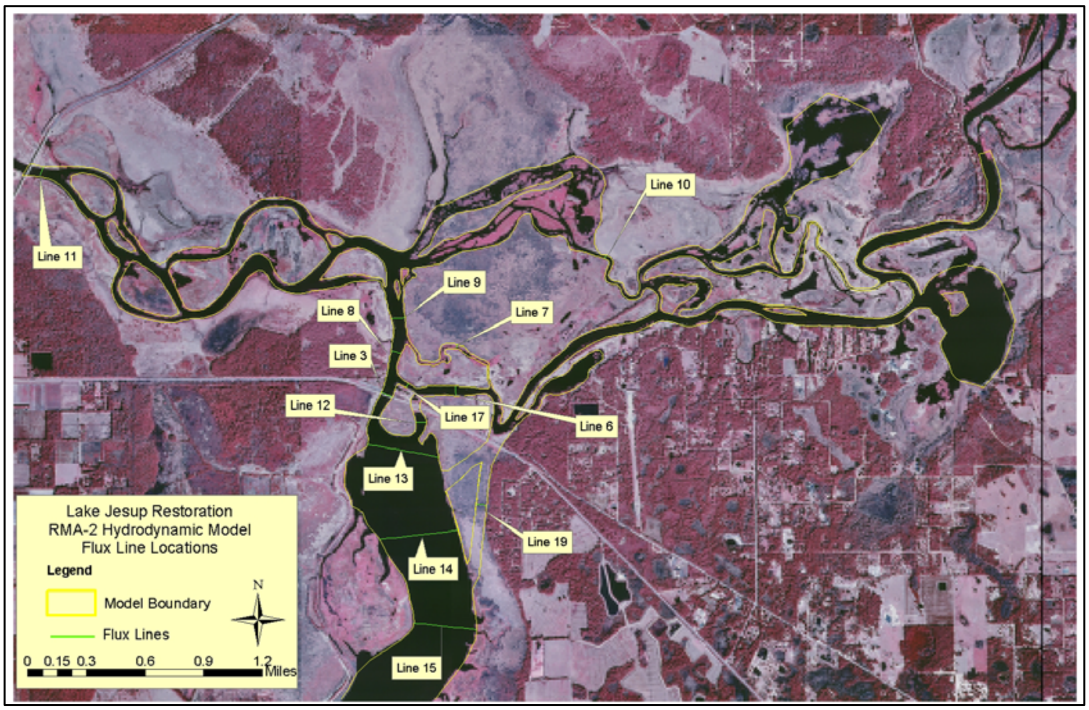

Figure 5. Lake Jesup Restoration RMA2 Hydrodynamic Model Flux Line Locations

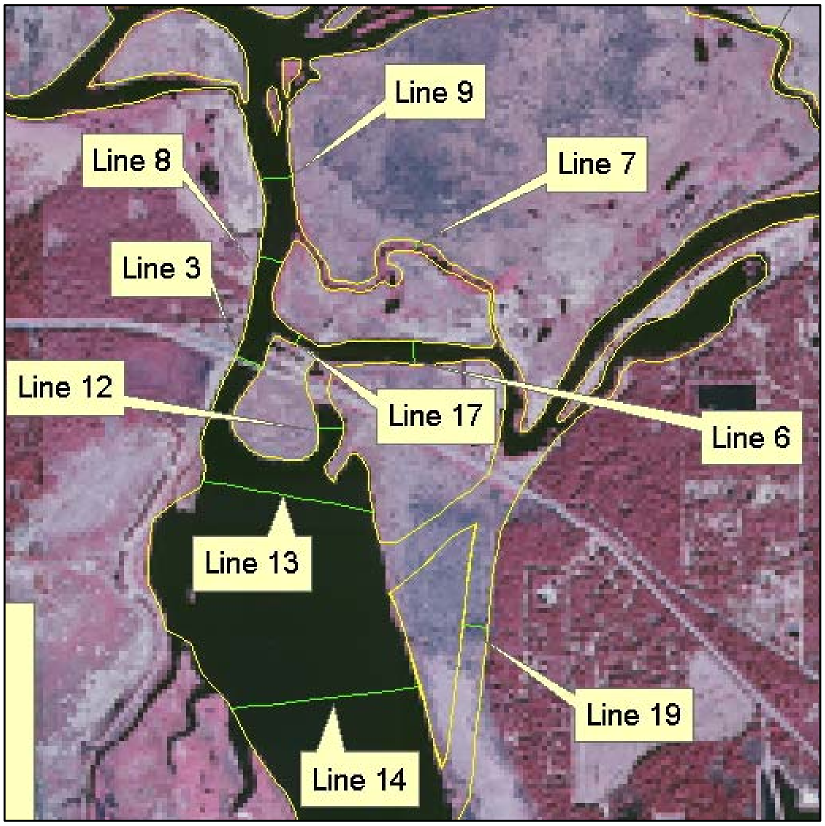

Figure 6. Lake Jesup Restoration RMA2 Flux Lines (mouth of Lake Jesup)

The existing conditions velocity vectors are shown in Figures 7 through 10. The vectors show there is flow in both the downstream and upstream directions; two time steps are compared to aid in showing the seiche between Lakes Jesup and Monroe.

Closing Government Cut forces flow both to the north through the braided channel area and to the south through Lake Jesup. The total flow through Government Cut does not get diverted into Lake Jesup. Figures 11 and 12 show the vector plots near Government Cut for Plans 2 and 4a, with Channels A and B open, Channel C closed for both plans; Government Cut is closed in Plan 2 and open in Plan 4a.

In addition to comparing areas with increased velocity, the area of increased flow was also reviewed. In this analysis, plots were developed showing areas with velocity greater than 0.01 feet per second (fps); this velocity was chosen for comparison purposes only, there is no established relationship between this velocity and sedimentation/scour. The total area does not include Channel A since it is open in each alternative, nor does it include areas south of Line 15, East of Line 6, or Government Cut because the focus of the study is near the mouth of Lake Jesup and the effects of opening Channel B and/or C. Each of the alternatives provides a greater area with velocity above 0.01 fps than existing conditions, Table 3 shows the results. Plots showing the area with velocity above 0.01 fps are shown in Figures 13 through 20. The simulation time used for illustration was chosen due to the magnitude of the velocity in the positive direction (flow out of Lake Jesup) for the existing conditions.

Table 3. Total Area with Velocity Greater than 0.01 fps

Plan	Existing	Plan 1	Plan 2	Plan 3a	Plan 3b	Plan 4a	Plan 4b	Plan 5
Area (ac)	150.84	229.80	208.07	225.76	228.82	199.05	197.59	253.61

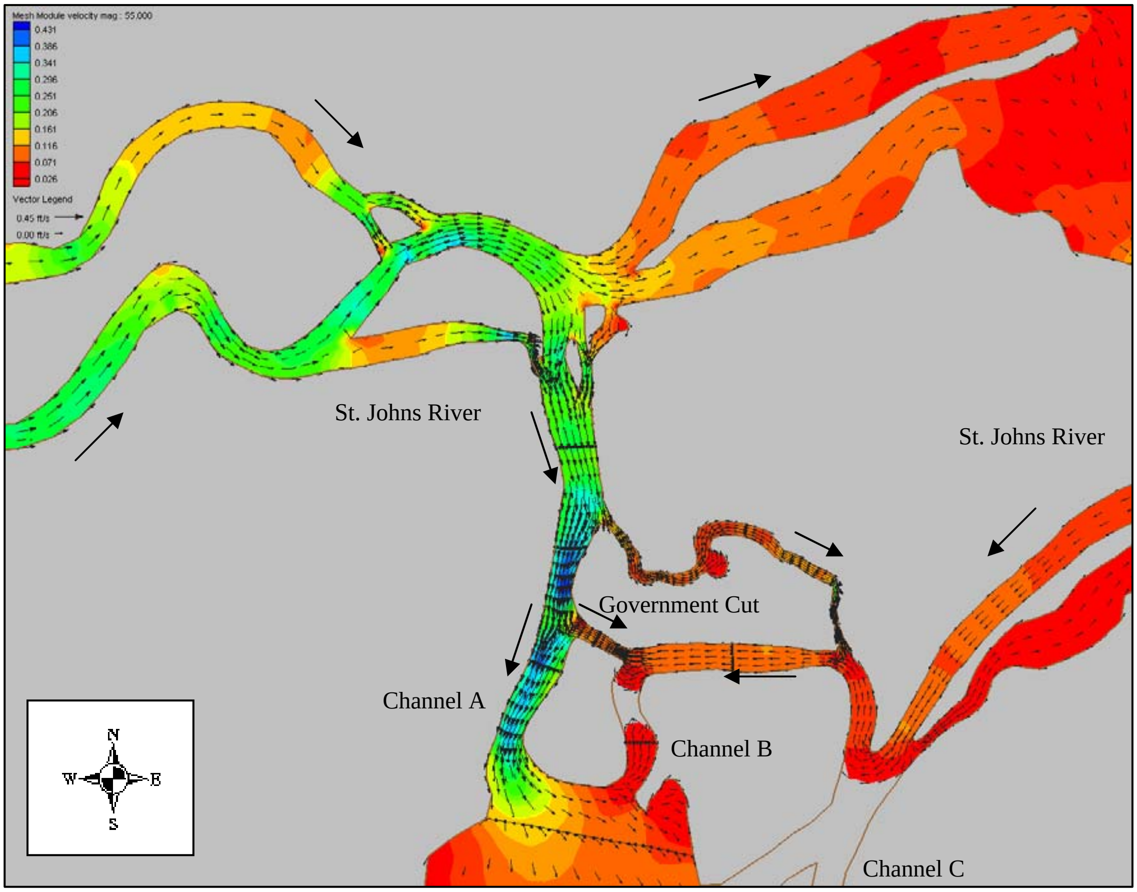

Figure 7. Existing Conditions Velocity Vector Plot

The arrows in Figure 7 show the direction of flow, note the southerly flow near the mouth of Lake Jesup (Time Step 55).

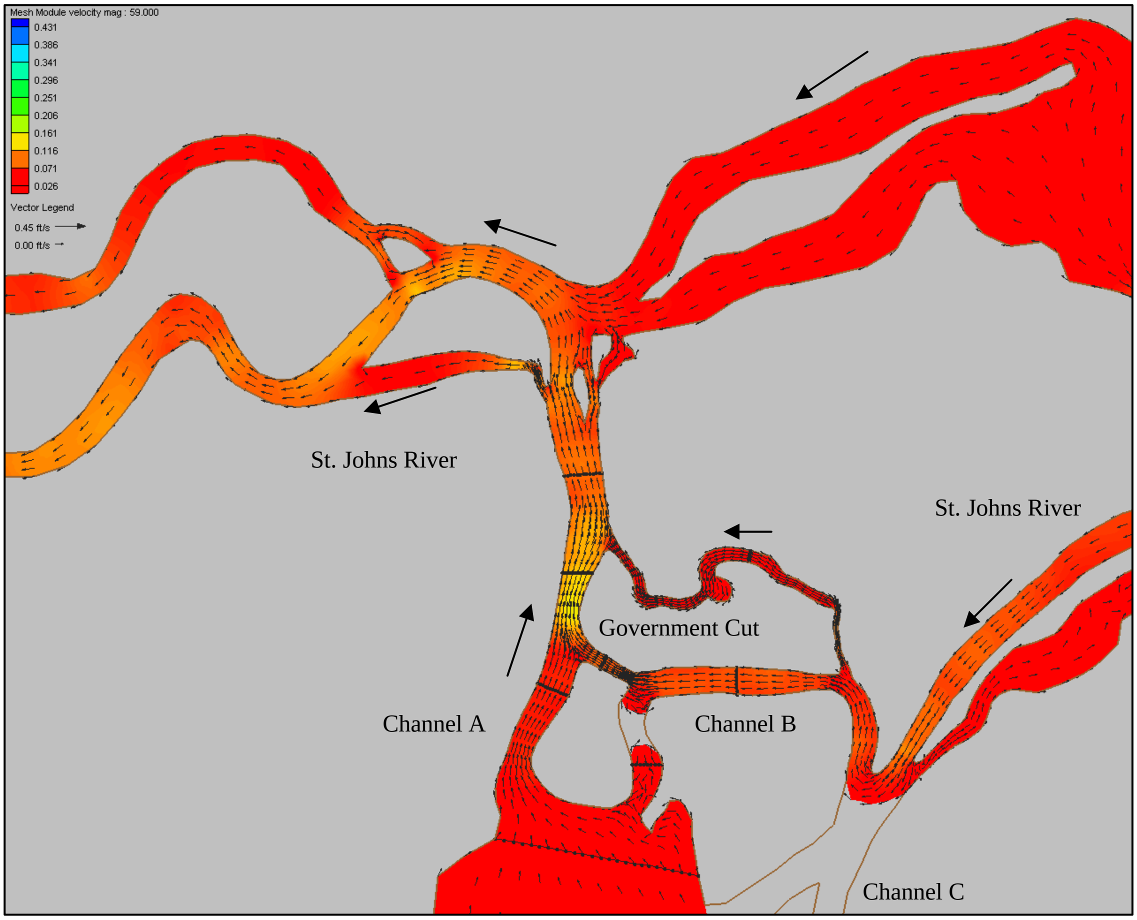

Figure 8. Existing Conditions Velocity Vector Plot

The arrows in Figure 8 show the direction of flow; Figure 8 when compared to Figure 7 aids in visualizing the seiche between Lakes Monroe and Jesup (Time Step 59).

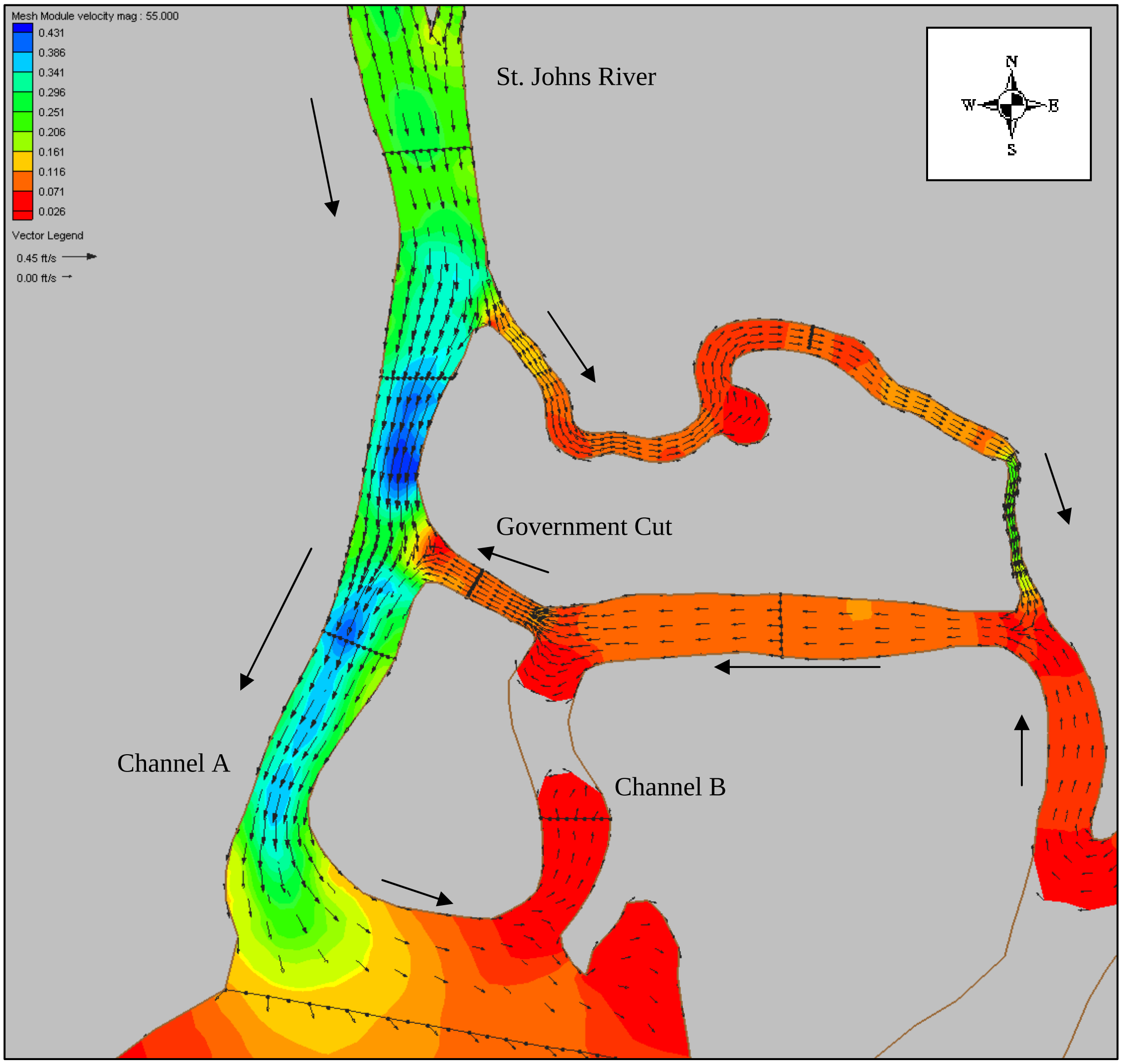

Figure 9. Existing Conditions Velocity Vector Plot, focused on Government Cut

The arrows in Figure 9 show the direction of flow, note the southerly flow near the mouth of Lake Jesup (Time Step 55).

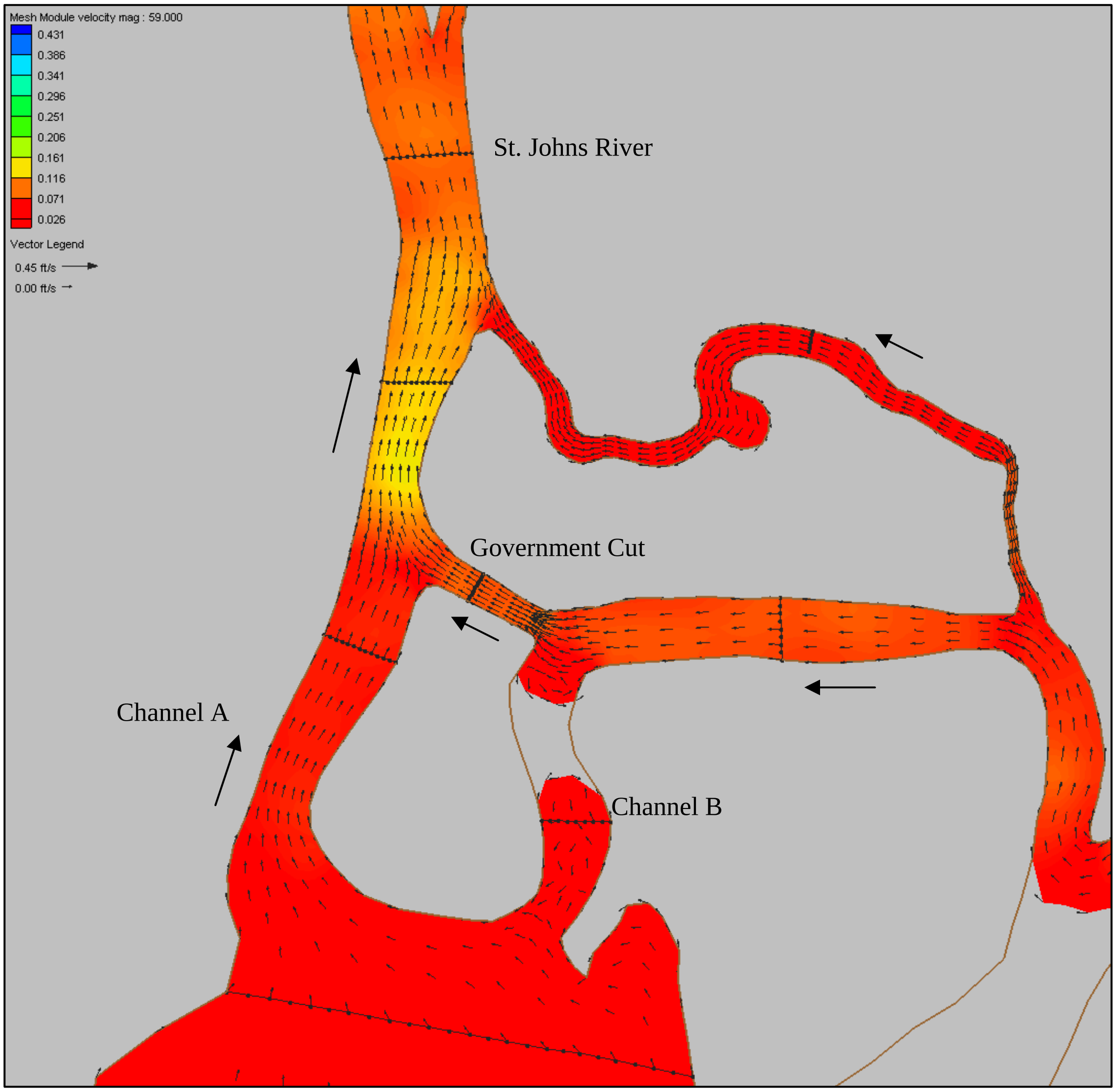

Figure 10. Existing Conditions Velocity Vector Plot, focused on Government Cut

The arrows in Figure 10 show the direction of flow; Figure 10 when compared to Figure 9 aids in visualizing the seiche between Lakes Monroe and Jesup (Time Step 59).

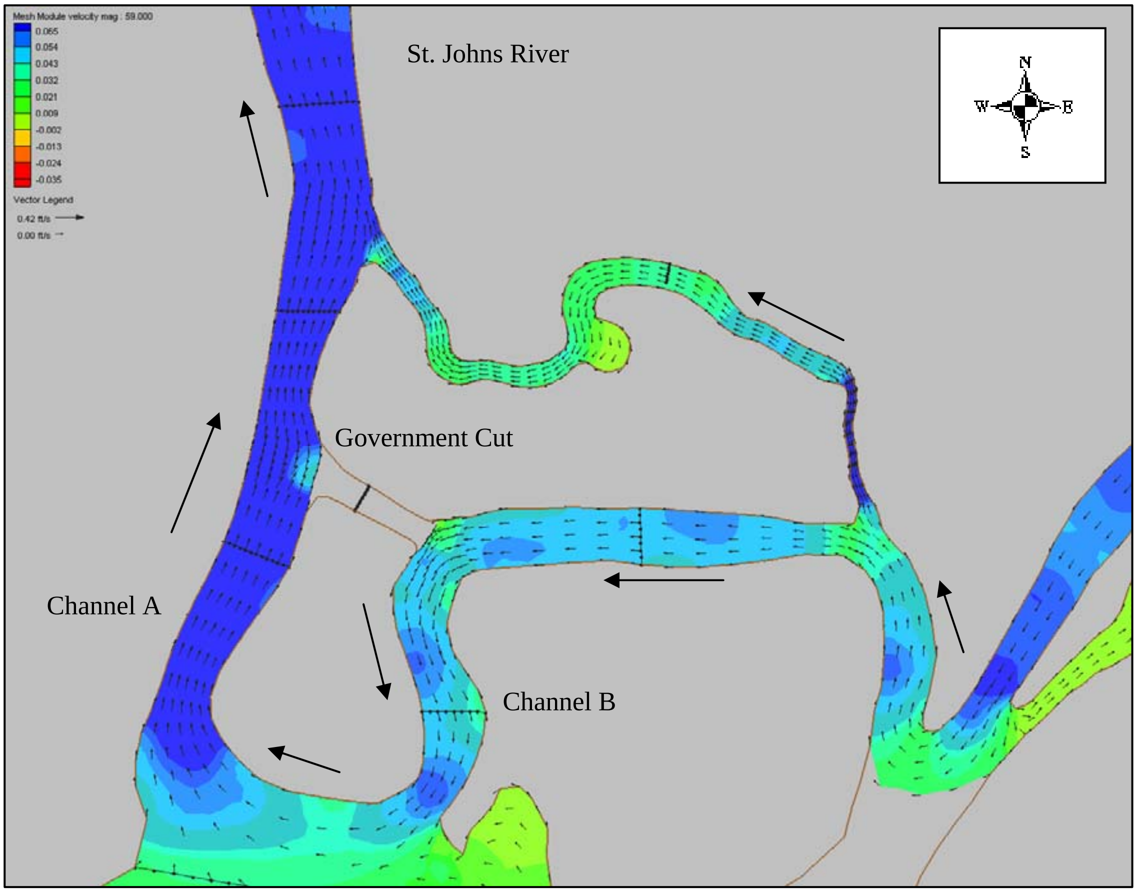

Figure 11. Plan 2 Velocity Vector Plot

The velocity magnitude and direction are shown in the above plot. Note the split in the flow from the channel leading to Government Cut and the channel north of Government Cut.

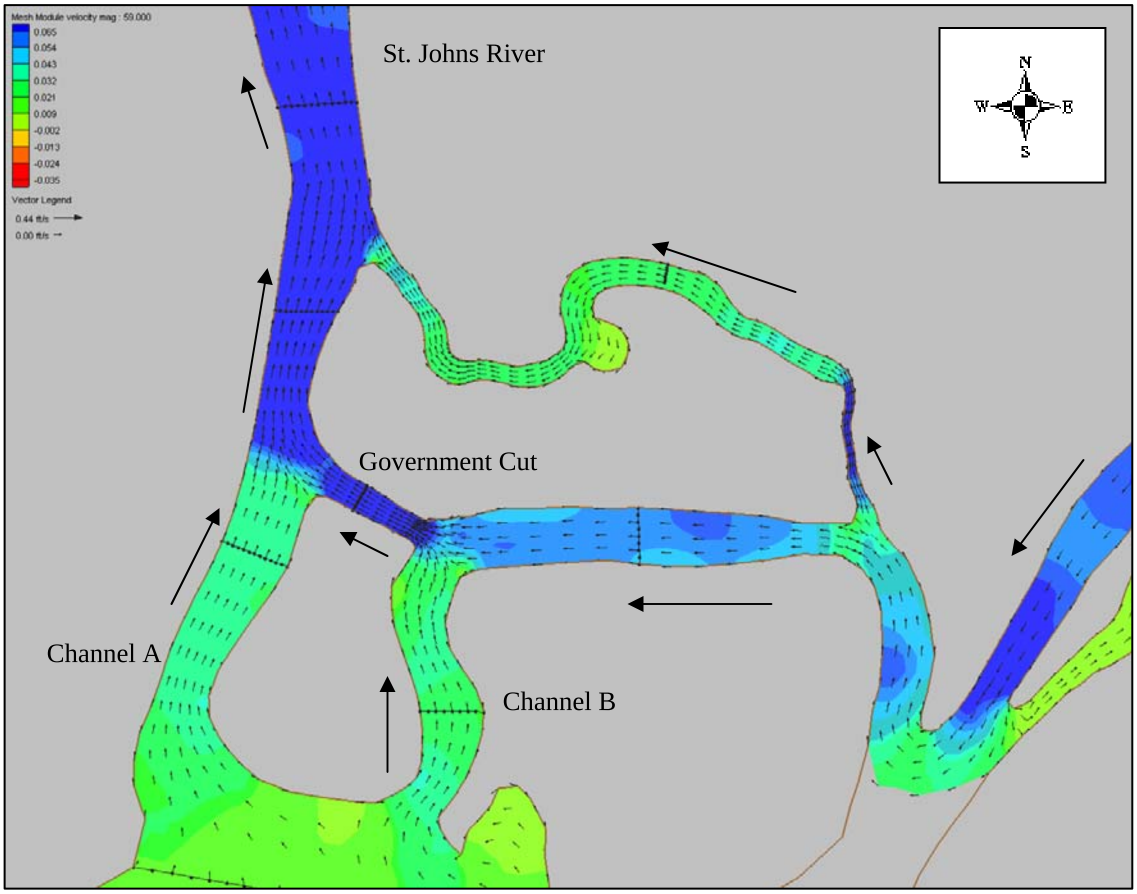

Figure 12. Plan 4a Velocity Vector Plot

The velocity magnitude and direction are shown in the above plot. Note the split in the flow from the channel leading to Government Cut and the channel north of Government Cut. At this particular time step, the flow out of Lake Jesup is through both Channels A and B. The flow out of Channel B shows there is not a constant flow into Lake Jesup through Channel B, showing the need for removing the boundary conditions from the project area.

Figure 13. Existing Conditions total area with velocity greater than 0.01 fps.

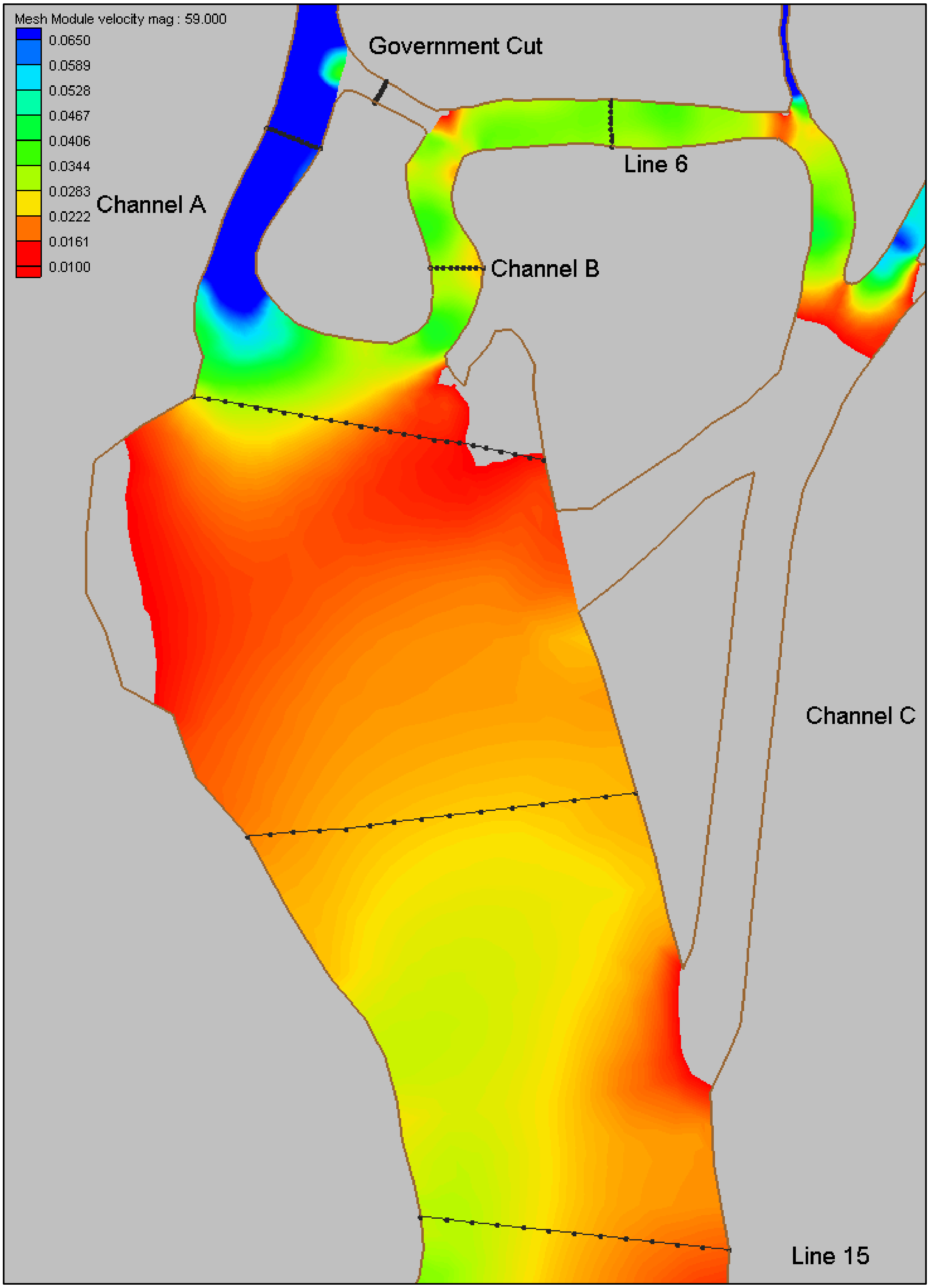

Figure 14. Plan 1 total area with velocity greater than 0.01 fps.

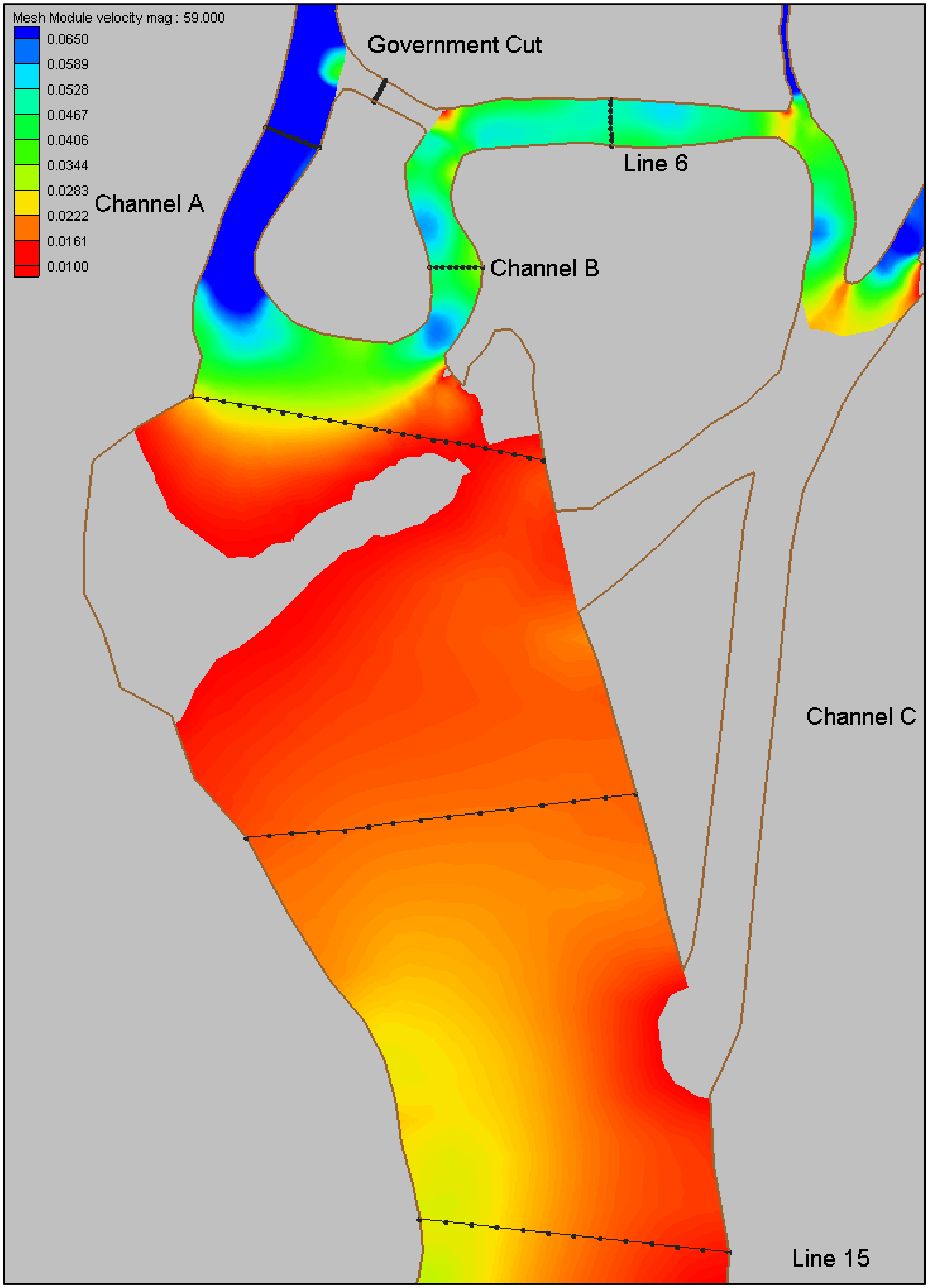

Figure 15. Plan 2 total area with velocity greater than 0.01 fps.

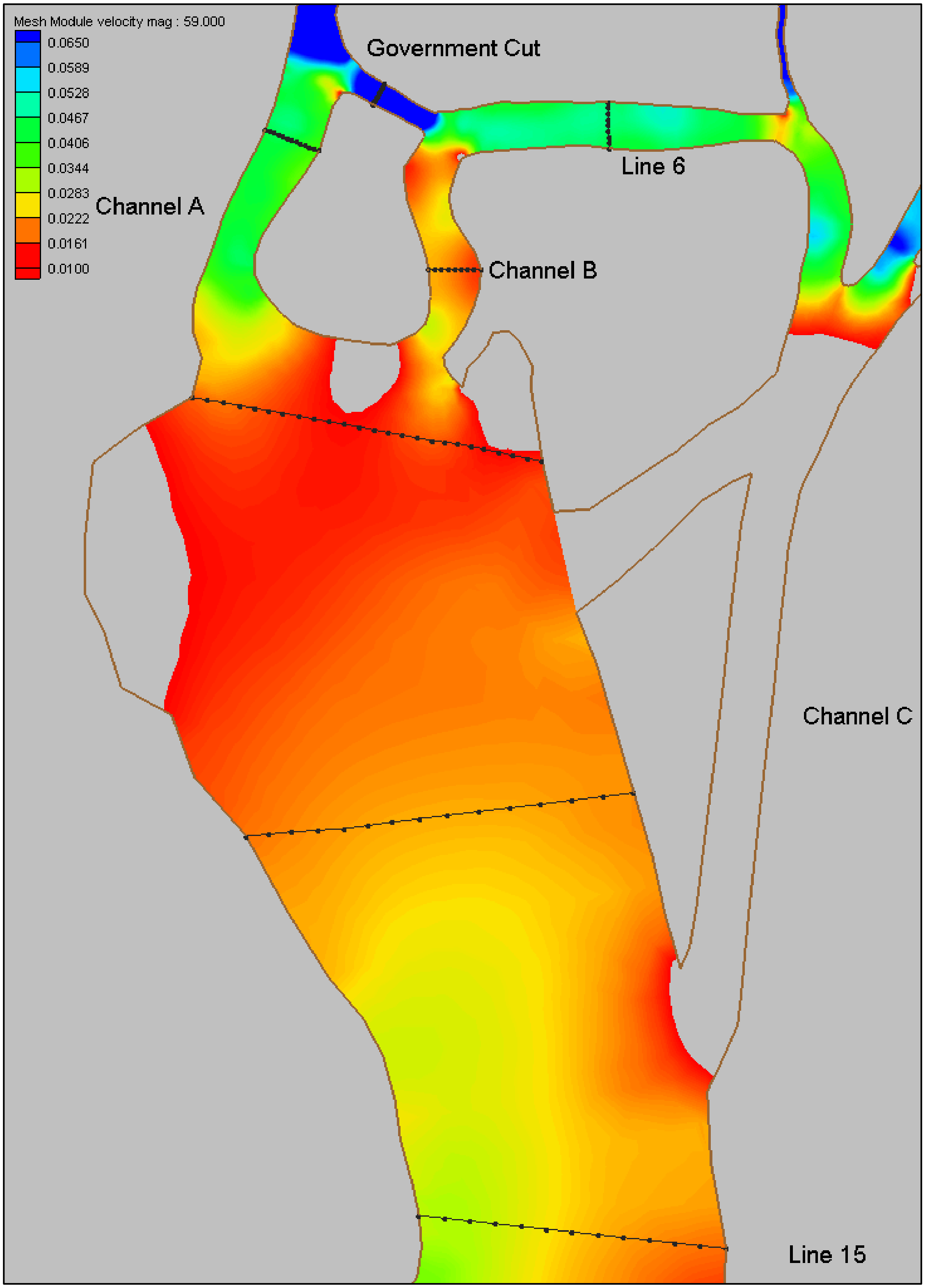

Figure 16. Plan 3a total area with velocity greater than 0.01 fps.

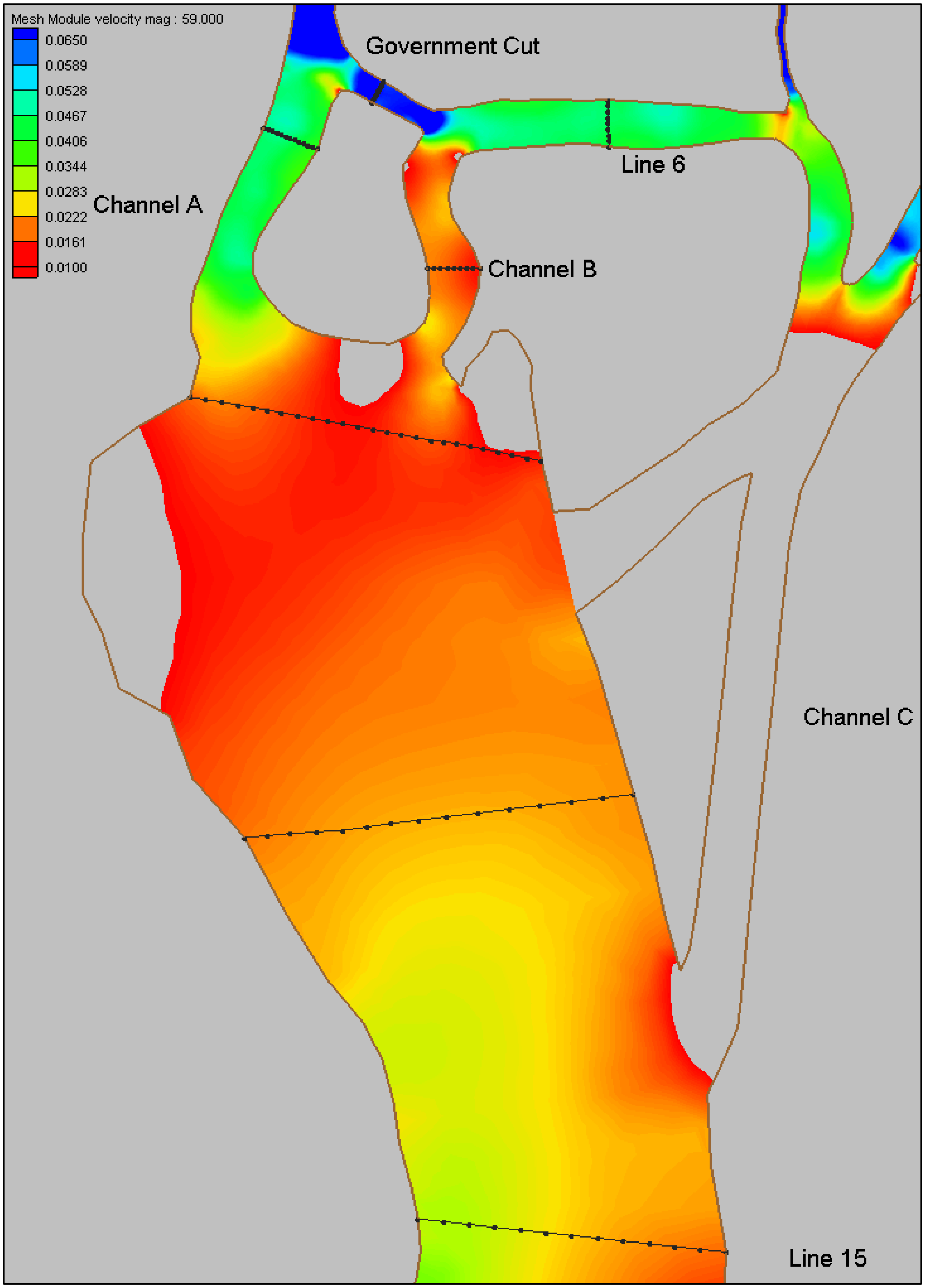

Figure 17. Plan 3b total area with velocity greater than 0.01 fps.

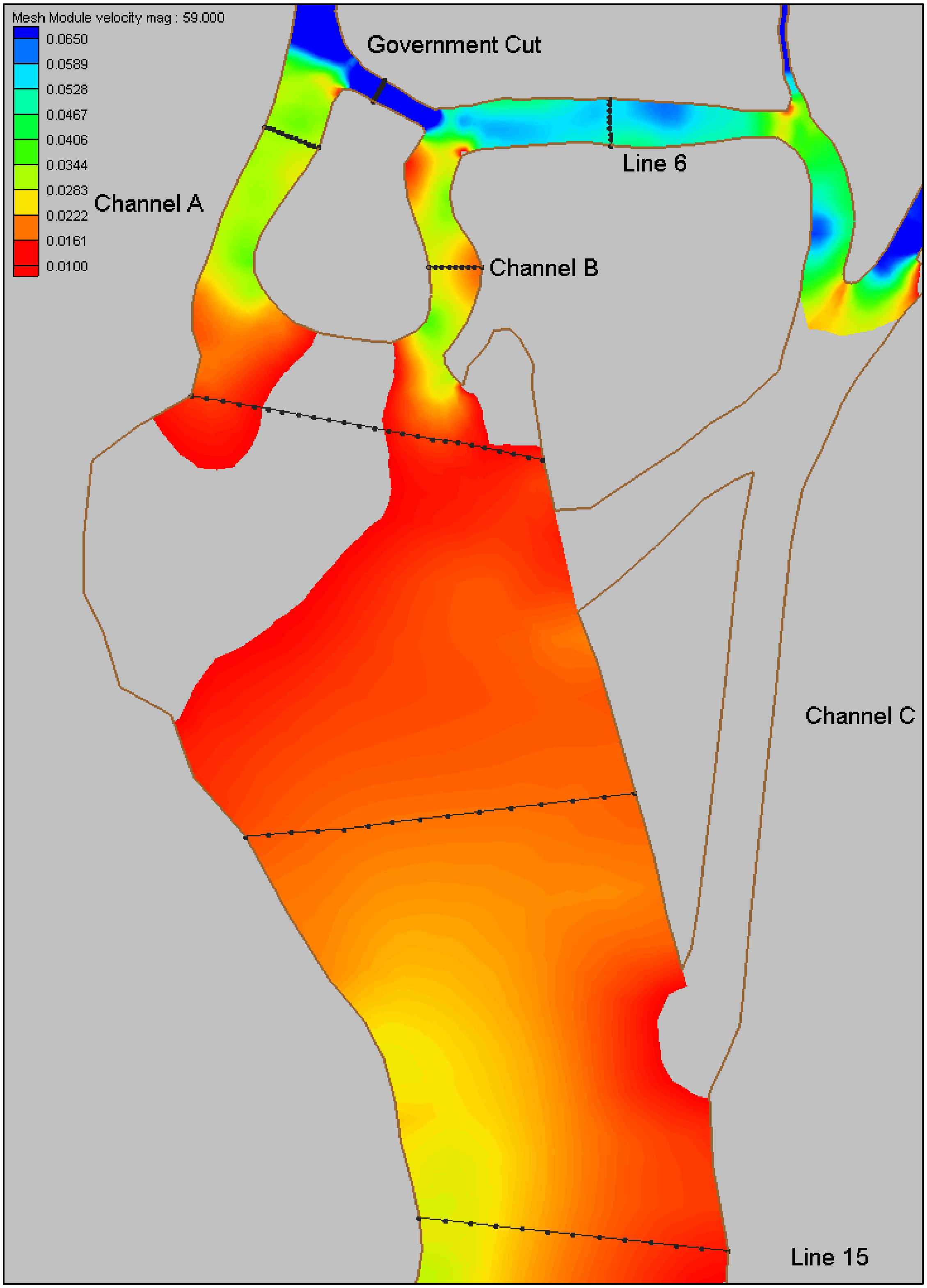

Figure 18. Plan 4a total area with velocity greater than 0.01 fps.

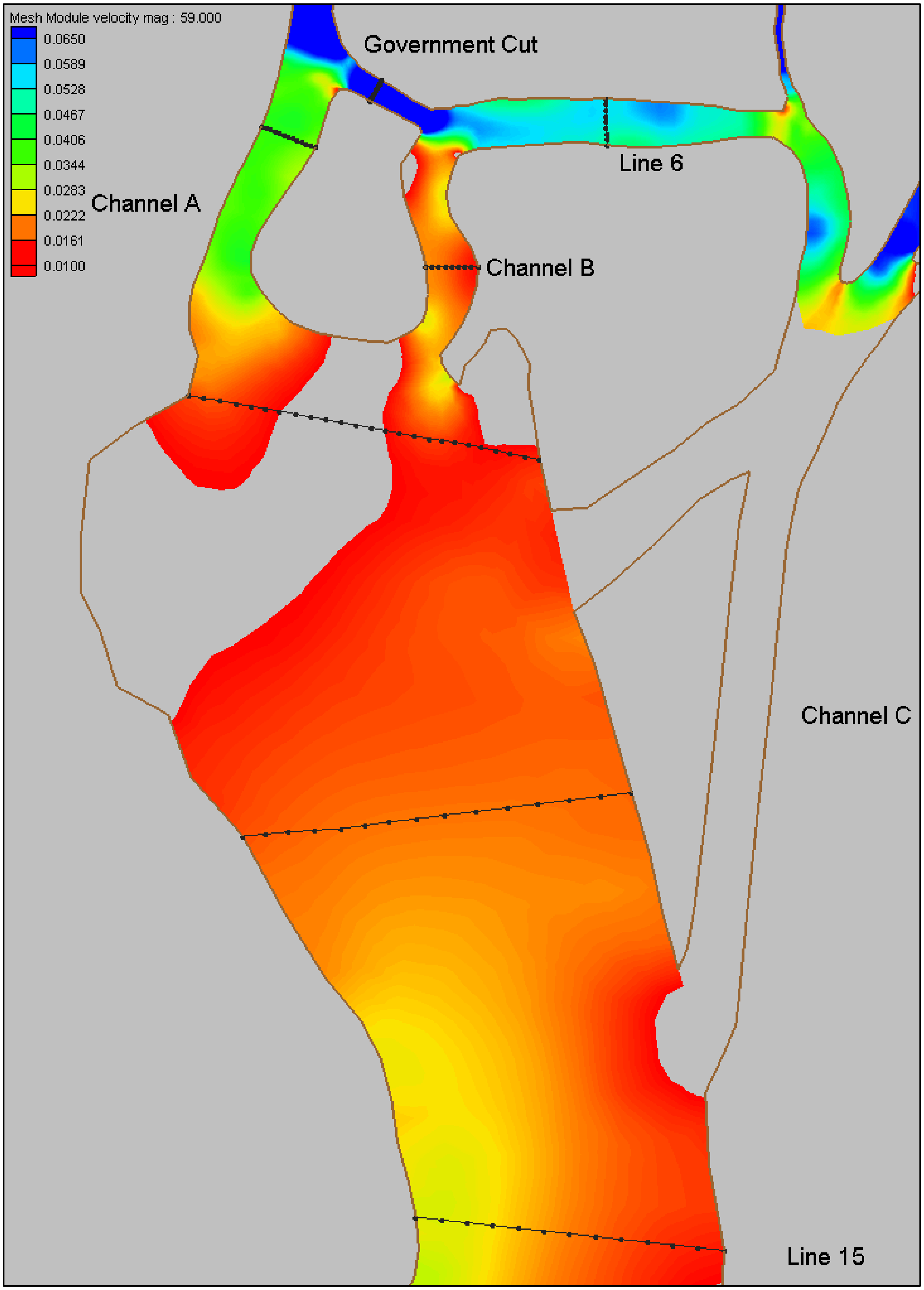

Figure 19. Plan 4b total area with velocity greater than 0.01 fps.

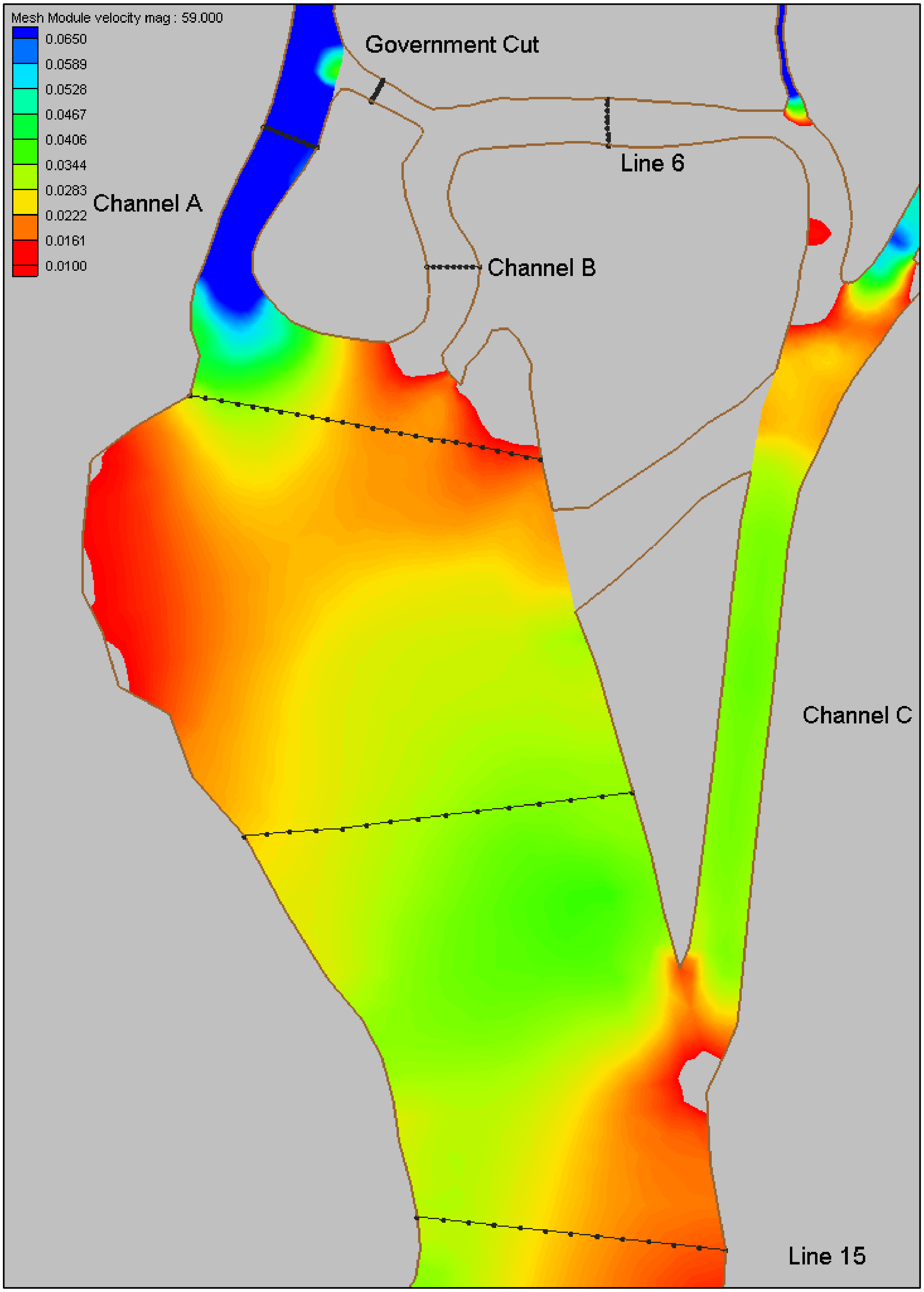

Figure 20. Plan 5 total area with velocity greater than 0.01 fps.

CONCLUSION

In conclusion, the purpose of the RMA2 model was to investigate possible changes in flow and velocity near the mouth of Lake Jesup. Prior to performing the modeling, a gage data study was conducted. This gage data study revealed a defined seiche between Lakes Monroe and Jesup; Lake Harney does not experience this seiche due to the head differential between the mouth of the lake and the braided channels near Lake Jesup.

The various alternatives changed the flow paths of the seiche; however none of the alternatives produced a run of the river type of flow through Channels B or C. All the alternatives experienced the seiche between Lakes Monroe and Jesup with various differences in flow rates and magnitude of velocity. Plan 5 (Channels A and C open, Channel B and Government Cut closed) provides the greatest increase in total flow from approximately 7275 cfs for Existing Conditions to approximately 16875 cfs, an increase of 9600 cfs.

Each of the various alternatives increases the area of flow with velocity above 0.01 fps. Existing conditions has an area of 150.84 ac with flow above 0.01 fps; Plan 5 produces the largest gain in area (253.61 ac), Plan 2 has the next largest gain in area (229.80 ac) with Plan 3b is similar in magnitude (228.82 ac).

Alternatives with Government Cut closed do not force flows exclusively through Lake Jesup. When Government Cut is closed the flow in the area is split between the braided channels, and Channels B and C into Lake Jesup.

After reviewing the RMA2 model results is it clear the various alternatives produce little change in the flows and velocity near the mouth of Lake Jesup. Due to the braided channels near the mouth of Lake Jesup closing Government Cut and opening Channels B and C do not force all of the flow into Lake Jesup. There is a localized increase in flow and velocity in the area immediately near the mouth of Lake Jesup.