26th to 34th Streets, West Avenue to Bay Avenue

Flood Mitigation Study

September, 2015

Prepared for City of Ocean City

Prepared by Michael Baker International

Contents

Executive Summary

The City of Ocean City (Ocean City) requested Michael Baker International (Michael Baker) to complete a flood mitigation study for the roughly 250 acres between 26th and 34th Streets and West and Bay Avenues. This area suffers repetitive flooding and lies nearly entirely below the Federal Emergency Management Agency (FEMA)'s base flood elevation. While the study area is subject to 1% annual chance (otherwise known as 100 year) flooding from the ocean, the city hopes to mitigate the more common rainfall events that have caused routine or nuisance flooding throughout the study area.

The goal of the study was to quantify the amount of rainfall throughout the study area, determine the amount of rainfall entering the storm sewers (runoff), and understand the performance of the existing system. To complete this goal, Michael Baker performed a watershed analysis and storm sewer analysis utilizing geographic information systems (GIS), Natural Resources Conservation Service (NRCS) rainfall data, National Oceanic and Atmospheric Administration (NOAA) tide data, and available storm sewer information obtained from Ocean City, field visits, and Google Earth.

Michael Baker completed the watershed analysis utilizing NRCS Technical Release 55 (TR-55) and the Environmental Protection Agency (EPA) Storm Water Management Model (SWMM) suite of modeling tools. Overall, the model contained 32,000 feet of pipe, 314 drainage structures, 110 routing points, and 73,000 feet of overflow paths. The model considered rainfall estimates for the 1-, 2-, 5-, and 10-year events. These storm events represent a higher frequency event than the FEMA flood insurance study models and depict the rainfall nuisance events.

Model results indicated that the system surcharges or floods to some extent for all recurrence intervals. This is due to the low elevations of the study area and the backwater condition provided at the outfall. This report discusses mitigation of this flooding by three different strategies: 1) pump system installation to aid the gravity controlled system, 2) improvements to the infrastructure, including new pipes and raising the roadway profile, and 3) green solutions involving small scale detention and infiltration.

Finally, the report discusses the cost of these options and a schedule of the options to best meet the community's needs. Phase 1 of the project includes the pump stations and the necessary sewer upgrades to accommodate only the pumps. The approximate cost of phase 1 is $750,000 per station or $2.25 million for the three stations targeting the biggest problem areas. Phase 1 also includes a maintenance plan that has an annual cost of $5,000 annually for servicing the pump stations throughout the city from the manufacturer plus routine maintenance performed by city staff. Phase 2 includes infrastructure improvements to the lowest roadways in the study area and has an approximate cost of $9.75 million. Phase 3 includes green infrastructure installations and comes with a cost of approximately $520,000 per infiltration system.

Introduction

Ocean City requested that Michael Baker complete a flood mitigation study for the drainage networks between 26th and 34th Streets and West and Bay Avenues (see the study area map on the following page). This study area suffers repetitive flooding and lies nearly entirely below FEMA's base flood elevation. While the study area is subject to 1% annual chance flooding from the ocean, the city hopes to mitigate the more common rainfall events that have caused nuisance or routine flooding throughout the study area.

Nuisance flooding causes damage to property, mosquito breeding, foul odors, increased degradation of the infrastructure, and falling real estate values among other costs to this community. The Mayor and City Council have made it a priority to gain understanding of this area's flooding and the magnitude of solutions required to improve the condition.

The study area is roughly 250 acres of residential, commercial, and open uses. Residential space makes up the majority of the study area, the lots consisting of an average of 60% impervious area. Drainage from the lots is conveyed over land to the roadway collection system and enters the storm sewers. Haven Avenue, Simpson Avenue, and West Avenue run north to south down the center of the island. These three streets have the lowest elevations in the study area. Elevations increase from this low point toward the beach and also toward the bay. The storm sewer network collects from the beach to the bay and drains to the bay.

Michael Baker developed an understanding of the problem, strategized solutions, and developed costs and schedules for the options.


26th to 34th Streets,
West Avenue to Bay Avenue
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26TH ST
27TH ST
28TH ST
W 28TH ST
29TH ST
30TH ST
32ND ST
33RD ST
34TH ST
SIMPSON AV
WESLEY AVE
WESLEY AV
WEST AVE
ASBURY AVE
CENTRAL AVE
BAY AV
BAYLAND AV
HAVEN AV
SUMMER CT
SUNNYSIDE CT
WATERWAY RD

Study Approach

The approach to this study was modeling the existing condition hydrology, storm sewers and tide impacts to understand the nature of the flooding. Understanding the flooding allows a qualitative and quantitative evaluation of various techniques for mitigating those flooding impacts. From these techniques, a phased solution to improve the situation is proposed for the study area. Lastly, the phased solutions include cost estimates to fully chart their potential.

Limited survey data was available for the study, so the modeling effort assumed ideal conditions for the network. Modeling of the network was completed for the 1-, 2-, 5-, and 10-year storm events. Outfalls for the system were given backwater conditions for two tide scenarios: elevation 0' NAVD88 and elevation 3' NAVD88. These tide conditions represent an approximate average tide and approximate high tide, respectively. Coastal storms can produce tides significantly greater than 3 feet, however those conditions are not being targeted for this mitigation effort. For reference the FEMA 1% annual chance (100-year) flood elevation is 9 feet in most of the study area.

Rainfall estimates for the study were gathered from the New Jersey NRCS website. The website lists 24-hour rainfall amounts for Cape May County that are summarized in Table 1. This rainfall data has been developed from the NOAA Atlas 14 dataset.

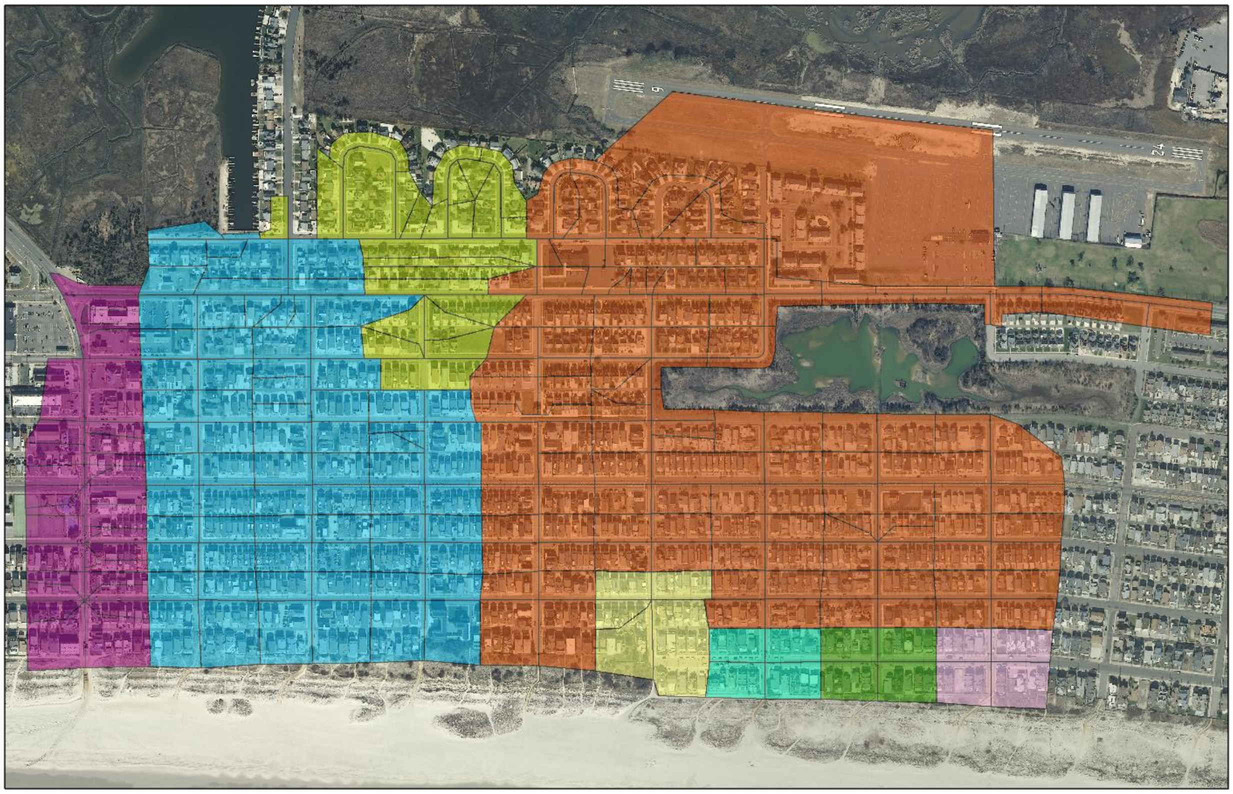
Cape May County 24-Hour Rainfall Frequency Data				
	1-Year	2-Year	5-Year	10-Year
Inches	2.68	3.27	4.24	5.08
Gallons (millions)	14.67	18.04	23.53	33.79

Once the hydrology was established, GIS enabled mapping of drainage areas and landuse. The large majority of the study area is residential, and that area was given a 60% impervious attribution. Commercial and open space make up the remainder of the study area as well as the roadway network. The roadway network consists of east-west numbered streets, north-south named streets, and north-south alleys separating residences. The roadway network is laid out in a grid pattern. Each grid typically consists of two north-south streets, two east-west streets, and one north-south alley that bisects the grid. Storm sewers are typically placed at the four corners of each grid.

Drainage areas were determined based on the location of the inlets with the understanding that water drains from the lots to the roadway collection system. The routing of the rainfall was modeled in EPA SWMM. This hydrologic and hydraulic modeling software was used not only for its principal task of storm sewer modeling, but also for its dynamic modeling of storm sewer overflows. This type of model displays water's movement from one drainage network to another and was critical for this study, since the center of the study area is the lowest and overland flow collects in that area.

The GIS data was imported to EPA SWMM. From the landuses and drainage areas developed in GIS, subcatchments were created in EPA SWMM. Rainfall collects in the subcatchments and can leave the subcatchments in three ways: infiltration, evaporation, or surface runoff. Each subcatchment also has a predefined depression storage factor and can store a certain amount of water on the surface. Surface runoff is determined by Manning's equation. Total runoff drains to the collection system. Horton's equation was used to determine the amount of infiltration that would enter the subsurface. For this study, no field testing was done to verify any modelling assumptions. See Figure 1 for the subcatchment map.

Figure 1 Subcatchments



Once the water drains from the subcatchment, it enters the storm sewer network. Flow routing within the conduits is governed by the Saint Venant flow equations. EPA SWMM has three routing methods: steady flow routing, kinematic wave routing, and dynamic wave routing. Dynamic wave routing was chosen for this modelling effort because it solves the complete one-dimensional Saint Venant flow equations. This method accounts for channel storage, backwater, entrance/exit losses, flow reversal, and pressurized flow. It is the most applicable method for systems with significant backwater influences, which is a significant contributing factor for the study area. Dynamic wave routing also enables the model to account for overland flow. Figure 2 shows the overland flow potential within the model. Over 73,000 feet of overland flow potential was studied. For this study, as water ponded at the inlets, the water could flow into the shoulders of the roadway and cross the center of the road.

Figure 2 Overland Flow

The storm sewer network was established from the available city data, field visits, and Google Street View. See Figure 3 for the storm sewer network. 32,000 feet of storm sewers were modeled and 314 drainage structures. Inverts were established from the available data sources and assumptions based on minimum slope and cover requirements. Field visits confirmed a large amount of sedimentation build-up in a majority of the inlets. The system's age of over 40 years also raises questions about the continuity of the network and its structural condition. The city has replaced some of the networks, removed the old pipes, and discovered that the bottoms of the pipes were completely deteriorated.

Figure 3 Storm Sewer Network

The city has upgraded the system in a number of ways over the years. One of those upgrades is the installment of a series of check valves. As they prevent rising tides from entering into the system, these check valves were considered in the model and applied where applicable.

The city recently installed infiltration at the beach blocks from 26th through 29th Streets. The infiltration was modeled, but infiltration parameters for the model were unknown since permeability tests were not completed as part of this study. Parameter guidelines for a subgrade of sand were used to estimate the amount of water that could enter the ground through these systems. Overflow from these systems would flow toward the center of the study area overland due to the elevation differences.

Environmental Investigation

Michael Baker performed a wetland investigation and delineation on March 23, 2015 for the project area. Prior to field reconnaissance, the project was located on 7.5 minute United States Geological Survey (USGS) Quadrangle mapping (Ocean City). This mapping was evaluated for topographic relief, drainage patterns, and subwatershed characteristics, which would suggest potential wetlands. The New Jersey Department of Environmental Protection (NJDEP) Freshwater Wetlands (FWW) and Upper Coastal Wetland Boundary mapping and the United States Fish and Wildlife Service (USFWS) National Wetland Inventory (NWI) mapping were examined for wetlands within the study area. Additionally, the United States Environmental Protection Agency (USEPA) Priority Wetlands List for New Jersey was reviewed.

Wetland areas were delineated following the Federal Manual for Identifying and Delineating Jurisdictional Wetlands (January, 1989) and the United States Army Corps of Engineer (USACE) Wetland Delineation Manual (1987) and the Interim Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Atlantic and Gulf Coastal Plain Region Version 2.0 (November, 2010). Use of these methodologies is required by the NJDEP Division of Land Use Regulation and the USACE. In accordance with these methodologies, the following parameters are characteristic of wetlands:

1. The land is dominated by hydrophytes;
2. The substrate is undrained hydric soil; and
3. The substrate is saturated with groundwater or flooded for a significant part of the growing season each year.

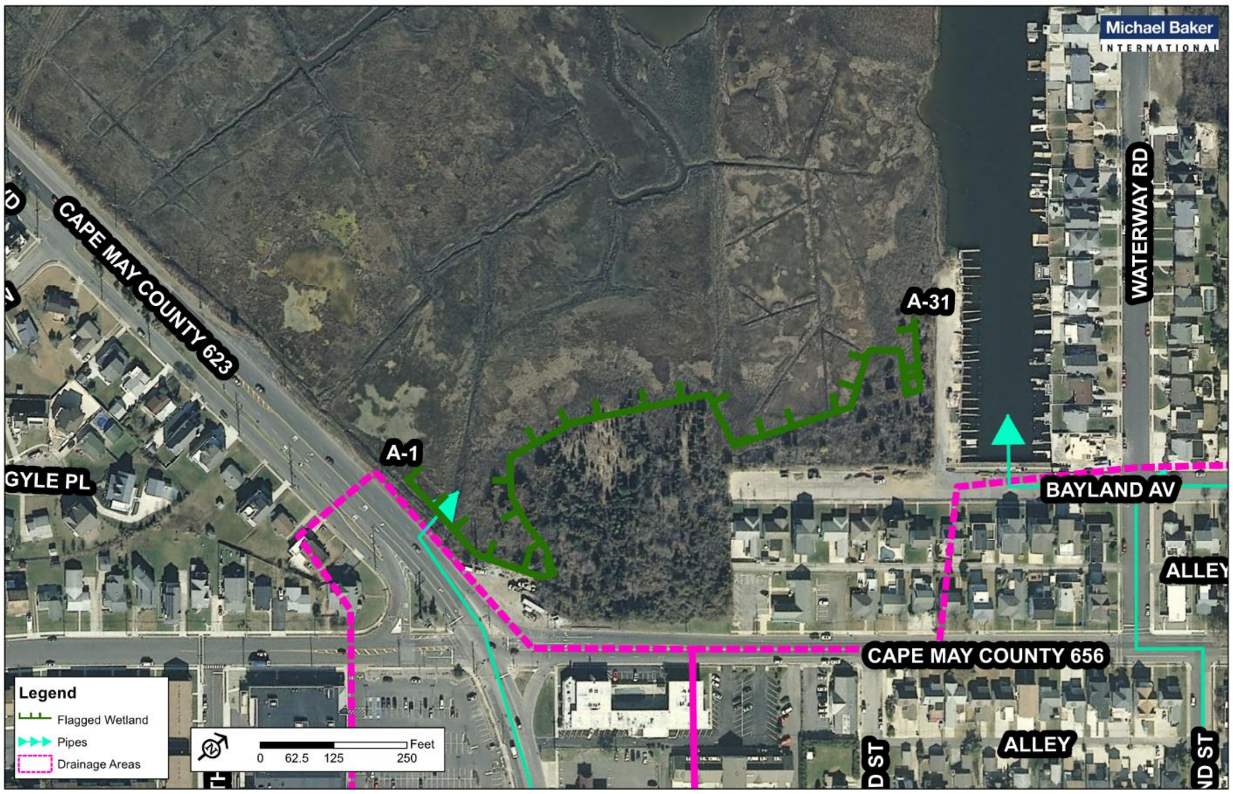
Positive indicators of the above listed parameters are the basis for wetland identification. All three parameters must be present in order for an area to be identified as wetland, unless abnormal or atypical conditions are determined to be present. There was no discrepancy in the use of these two methodologies.

In order to delineate the jurisdictional wetland limits, a series of field observations were made to confirm the presence or absence of positive wetland indicators. First, the dominant vegetation was identified and a determination as to the presence of hydrophytic vegetation was made. If a dominant hydrophytic vegetation community was identified, then a soil auger was used to take samples at the areas along the vegetation community edge that supported a dominance of facultative, facultative wet or obligate plant species to identify the presence of hydric soils. Additionally, the area was also investigated for indicators suggesting clear evidence of wetland hydrology.

The wetland delineation was limited to the vicinity of Roosevelt Boulevard and Bay Avenue, where a pump station is being considered. However, during the wetland investigation, coastal wetlands were identified adjacent to the Ocean City Municipal Airport where outfall improvements and a pump station are also currently being considered. In addition, the Howard S. Stainton Wildlife Refuge (HSSWR), located on Bay Avenue between 23rd and 30th Streets, was also identified within the vicinity of the project area. The HSSWR was converted to natural wetland habitat for local and migrating wildlife.

One wetland, Wetland A, was delineated during the wetland investigation in the vicinity of Roosevelt Boulevard and Bay Avenue. Wetland A is mapped on the NWI as a palustrine emergent persistent seasonally-flooded wetland and as a saline marsh on the NJDEP FWW mapping. Portions of Wetland A are located within the upper wetland boundary limit of the NJDEP Coastal Wetlands mapping. The site investigation confirmed the presence of a saline marsh wetland. Common reed (Phragmites australis, FACW) was dominate along the wetland/upland boundary. The upland species consisted of eastern red cedar (Juniperus virginiana, FACU), northern bay berry (Morella pensylvanica, FAC), and switchgrass (Panicum virgatum, FAC). Soil samples extracted in the field met the criteria for Sandy Redox (S5) and Dark Surface (S7). Evidence of wetland hydrology observed includes a high water table (A2), drift deposits (B3), drainage patterns (B10), geomorphic position (D2), and a positive FAC-Neutral test (D5).

Figure 4 - Delineation of Wetland A



The wetland identified within the project area is subject to regulation by the NJDEP and the USACE. Depending on where the pump stations are located, and if impacts to wetlands and water resources are encountered, the NJDEP may require a Coastal Area Facility Review Act (CAFRA) Area Permit (N.J.A.C. 7:7-2.1 (a)2), Coastal Wetlands Permit (N.J.A.C. 7:7-2.2 (a)12), Waterfront Development Permit (N.J.A.C. 7:7-2.3(d)), and/or a FWW General Permit 11 for Outfalls and Intake Structures. Additionally, if the proposed project results in greater than 5,000 square feet or more of ground disturbance, a Soil Erosion and Sediment Control application will need to be submitted to the appropriate Soil Conservation District.

The project area is located within the CAFRA boundary, as such, a CAFRA Permit may be required if the pump station is installed in the CAFRA area between the mean high water line of any tidal waters, or the landward limit of a beach or dune, whichever is most landward, and a point 150 feet landward of the mean high water line of any tidal waters or the landward limit of a beach or dune, whichever is most landward. Additionally, Wetland A was partially delineated within the upper wetland boundary limit of the NJDEP Coastal Wetlands mapping. If the proposed project activities result in any filling, excavation or construction of any structure in the portion of the wetland that is mapped as a coastal wetland, then a NJDEP Coastal Wetland Permit will be required. A NJDEP FWW GP 11 may also be warranted if the installation of the pump station impact any portion of Wetland A that is regulated under the Freshwater Wetlands Protection Act Rules (N.J.AC. 7:7A).

As mentioned above, Wetland A is also regulated by the USACE and if the proposed project results in impacts to waters of the United States a Nationwide Permit (NWP) 7 (Outfall Structures and Associated Intake Structures) for the installation of the pump station and NWP 12 (Utility Line Activities) for the proposed replacement of existing pipes may be warranted.

Both the aforementioned NJDEP permits and USACE permits will require cultural resources review. Based on the nature of the proposed activities and developed land use of the project area, it is not anticipated that the project will result in adverse impacts to historic structures or archaeological sites. However, formal coordination with the NJ State Historic Preservation Office is anticipated.

The permit requirements for the project will be re-evaluated during final design of the project.

Model Findings

Through the four various rainfall events and two different tide options, a total of eight scenarios were run for the purposes of this study. All of the modeling scenarios produced some level of roadway flooding. The 1-year storm with the low tide boundary condition produced flooding in the lowest areas of the study area on Haven and Simpson Avenues. The less frequent 5- and 10-year events produced significantly more roadway flooding with longer durations. The high tide event of 3’ NAVD88 causes significant flooding at all levels. The model assumes empty and intact pipes at the start of each run.

Holistically, the model revealed a number of issues. Pipe capacity, travel length, structure condition, and overland flow are among those issues. Areas along Haven Avenue, Simpson Avenue, and West Avenue contain the highest number of areas below 3’ NAVD88. Areas below this high tide elevation will flood whenever it rains during high tide under existing conditions. Check valves in the system prevent the bay from entering the system, but in order for water to exit the system by gravity the water elevation on these streets would need to be above 3’ NAVD88. In many instances this would be a flood condition.

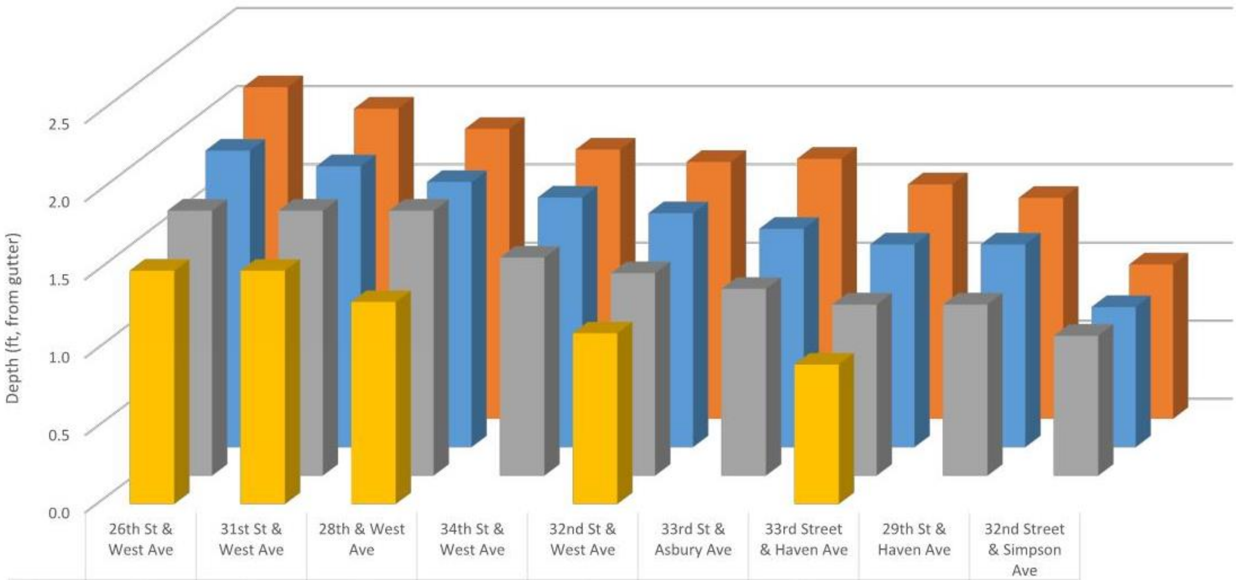
The city has historically experienced flooding at high tides even without a rainfall event. This situation indicates an issue with storm sewer continuity. High tides can impact groundwater elevation and force water through the deficient storm sewer and drainage structures. See Figure 5 for a location map of the outfalls. The highest percentage of drainage travels to outfalls 3, 4, 5, and 6. The water needs to travel a long distance at a very low slope, causing capacity problems during low tides. Figure 6 shows the areas of the study that show the greatest flooding potential.

Figure 5 Outfall Locations

Figure 6 Highest Flood Potential

The following table and graph show the predicted flood depths at the most susceptible areas of the study area:

Figure 7 - Flood Depths



	26th St & West Ave	31st St & West Ave	28th & West Ave	34th St & West Ave	32nd St & West Ave	33rd St & Asbury Ave	33rd Street & Haven Ave	29th St & Haven Ave	32nd Street & Simpson Ave
1-year	1.5	1.5	1.3		1.1		0.9		
2-year	1.7	1.7	1.7	1.4	1.3	1.2	1.1	1.1	0.9
5-year	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.3	0.9
10-year	2.1	2.0	1.9	1.7	1.6	1.7	1.5	1.4	1.0

The results indicate significant depths in the roadway gutters of the study area for the four modeled storm events. As the flood waters crest above the inlets water is quickly dispersed in the roadway gutters. Flood waters recede in the modeled storms in approximately 5-6 hours. Flood depths remain similar across the modeled storm events. This is significant because it indicates a substantial role that the tide boundary condition has on the system performance.

Mitigation Recommendations

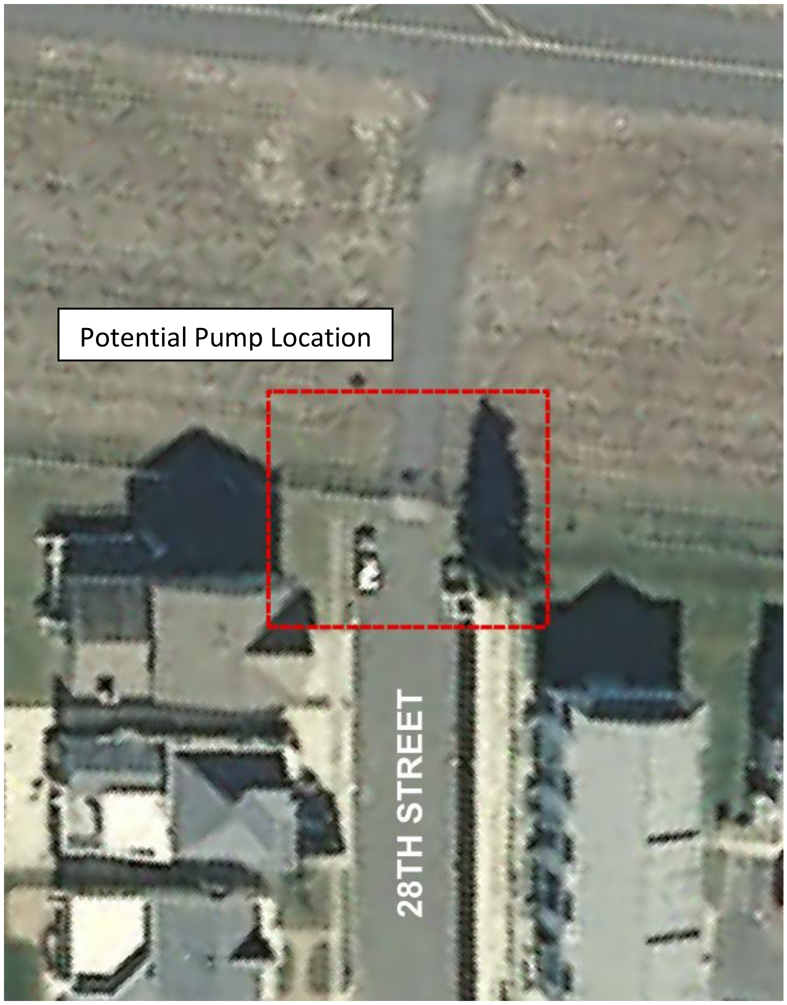
Mechanical Solutions

Installing pump stations at outfalls 3, 4, 5, and 6 would create a mechanism to assist the conveyance of water from the low points along Haven Avenue, Simpson Avenue, and West Avenue. The drainage network could be entirely replaced to create a pump dependent system, or the pumps could be added to the existing systems to assist the gravity flow mechanisms currently in place. Based on the modeling results, a pump solution would enable the system to combat the tidal impacts controlling the system performance.

For the purposes of this study and the cost estimate, the pumps are assumed to be an offline solution that would require limited upgrade of the upstream drainage network. This solution would call for a diversion structure to be added near outfalls 3, 4, 5, and 6. Outfalls 3 and 4 could likely be conveyed to one system. Outfalls 5 and 6 would most likely need their own systems due to the demand. As an estimate, it is assumed that the stations should be able to handle 20,000 gallons per minute based on the existing size of the upstream system. It is also suggested that the stations themselves be larger than required in order to allow for additional pumps being added for an increase in demand. Two proposed locations are presented in Figures 8 and 9. A third station would be ideal somewhere on the airport property.

Figure 8 - Outfall 3&4 Approximate Pump Station Location

Figure 9 - Outfall 5 Pump Station



Infrastructure Improvements

Improving the drainage system for the entire study area and raising Haven Avenue, Simpson Avenue, West Avenue, and the related numbered streets would provide significant improvements to the flooding issue. Currently this area lies lower than the beach and bay sides of the study area. The model revealed that flooded water on the streets would flow to the center of the study area and create a “bathtub” effect.

Field visits and existing survey have highlighted the potential for some elevation increases to these roadways while still collecting drainage from the resident’s properties. The network itself should also be laid out with the intention of keeping the inlets offline from the main storm sewers. This layout will allow maximum slope from inlets to the main and eliminate extra pipe length on the main sewers. Smaller dual or triplex pipe mains should also be considered to maximize slope in the network.

Existing pipes should be replaced with ductile iron pipe or a properly anchored plastic pipe. Ductile iron has the advantage of requiring less cover from the road traffic due to its durability, but it comes at a higher cost and will need to be wrapped in a plastic cover to prevent saltwater deterioration.

Green Infrastructure Strategies

Green infrastructure strategies include infiltration and storage. Due to the soil conditions on the barrier island, infiltration is anticipated to only be successful close to the beach where sandy soils would allow for water to drain. Rain barrels and rain gardens should be considered on properties to retain water and lower peak surges in the drainage system.

For infiltration, the city has had success in separating the storm sewers at the beach blocks from 26th Street to 29th Street into infiltration under the roadway. It is proposed that concrete chambers be installed under the beach block from 30th–34th Street to remove drainage areas from the overburdened systems. Soil borings or test pits will need to be collected to determine the infiltration capacity of the soil in this area. The system will still need to have overflow capacity back into the existing system, but this solution should remove significant flow from the system surcharging the roadways.

Phased Approach

These mitigation solutions are separated into the three previously mentioned categories and can be installed independent of one another. By creating offline pump stations, the drainage systems would operate by gravity as they do now, but as the system begins to flood the pump stations would be engaged to keep up with the demand. Though the systems would require limited improvements upstream from the pipe networks, they would need upgrades by way of new pipes to the outfalls to handle the pumped flow. These stations would significantly alleviate flooding in the area but could require permitting, depending on the locations selected. The pumps' electrical infrastructure would also need upgrades to provide a three-phase supply.

The roadway and drainage improvements can happen independent of the pump stations and green infrastructure improvements but require longer design time. This modification would improve the roadway conditions and raise the drainage network. The pump station design would allow for these improvements with limited replacement of that system.

The green infrastructure solutions can also be constructed parallel to the other mitigation solutions. This category of improvements would require city contracts for the large under-the-road infiltration facilities, but the rain barrels and rain gardens would be put in place by the property owners. Programs and grants are available to obtain materials and give training for the construction of these devices to residents. This initiative has the smallest flooding reduction impact but also comes with the smallest costs.

Cost Estimates

Phase 1 – Pump Stations

Cost Per Station	
Mobilization	$ 40,000.00
Three (3) 80 HP Pumps and Cables	$ 135,000.00
Pump Controls	$ 40,000.00
Internal Piping	$ 25,000.00
Outfall Pipe	$ 100,000.00
Diversion Manhole	$ 50,000.00
Piling Support	$ 50,000.00
Concrete Station	$ 150,000.00
Electric Upgrades	$ 100,000.00
Soil Erosion Sediment Control	$ 10,000.00
Stairs and Other Access Requirements	$ 50,000.00
TOTAL:	$ 750,000.00
TOTAL FOR 3 STATIONS:	$ 2,250,000.00

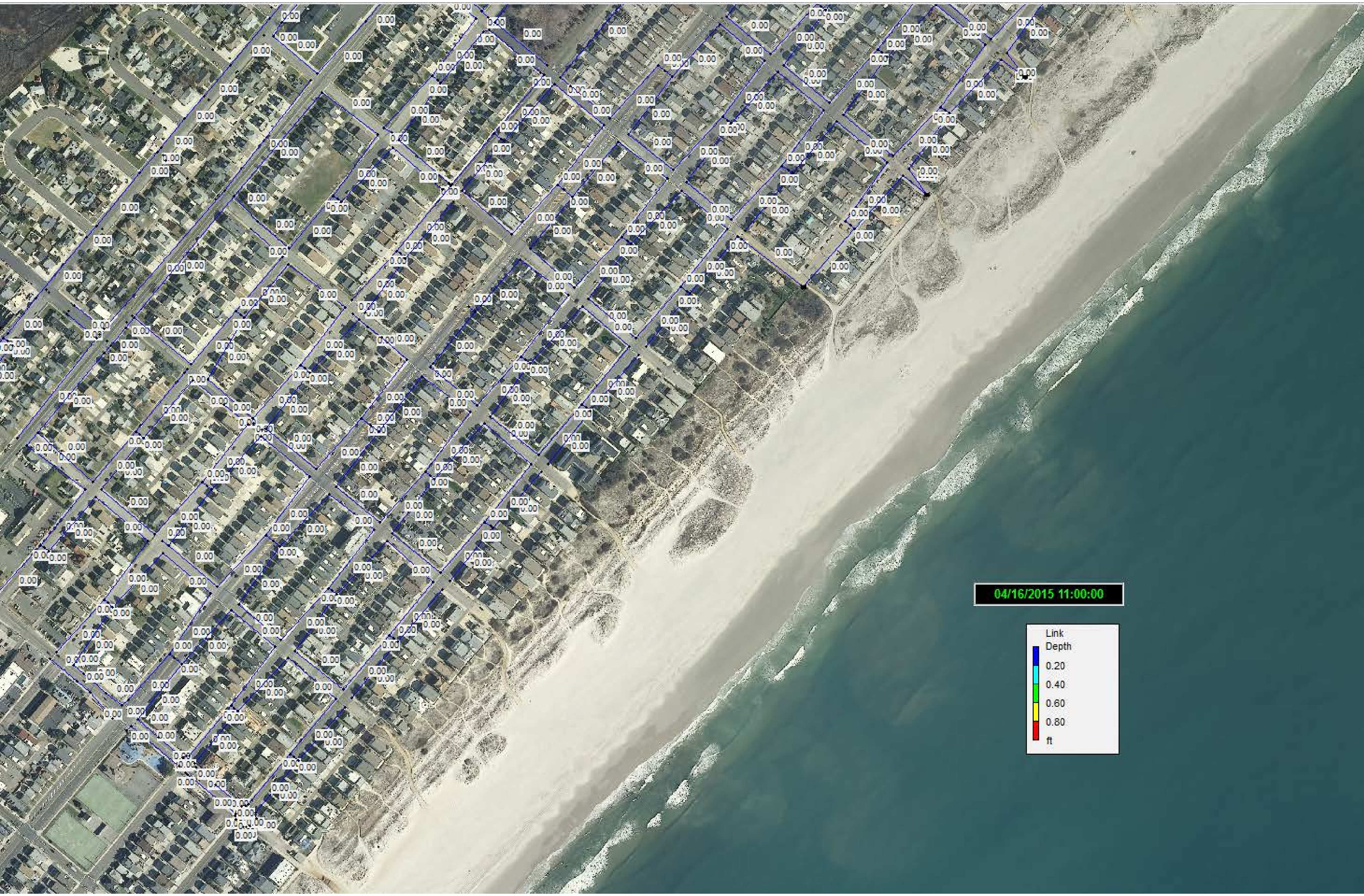
Phase 2 – Roadway and Drainage Network Improvements

Upgrades to Simpson, Haven, West and Numbered Streets	
Necessary Drainage System Upgrades	
Mobilization	$ 75,000.00
Soil Erosion Sediment Control	$ 30,000.00
Pavement Upgrades	$ 4,500,000.00
Drainage Upgrades	$ 3,600,000.00
Sidewalk Improvements	$ 1,400,000.00
Utility Conflicts	$ 100,000.00
Traffic Control	$ 50,000.00
TOTAL:	$ 9,755,000.00

Phase 3 – Green Infrastructure Strategies

Cost Per Unit	
Mobilization	$ 40,000.00
Soil Erosion Sediment Control	$ 5,000.00
Drainage Upgrades	$ 75,000.00
Infiltration System	$ 400,000.00
TOTAL:	$ 520,000.00

Appendix – 10 Year Event Gutter Flooding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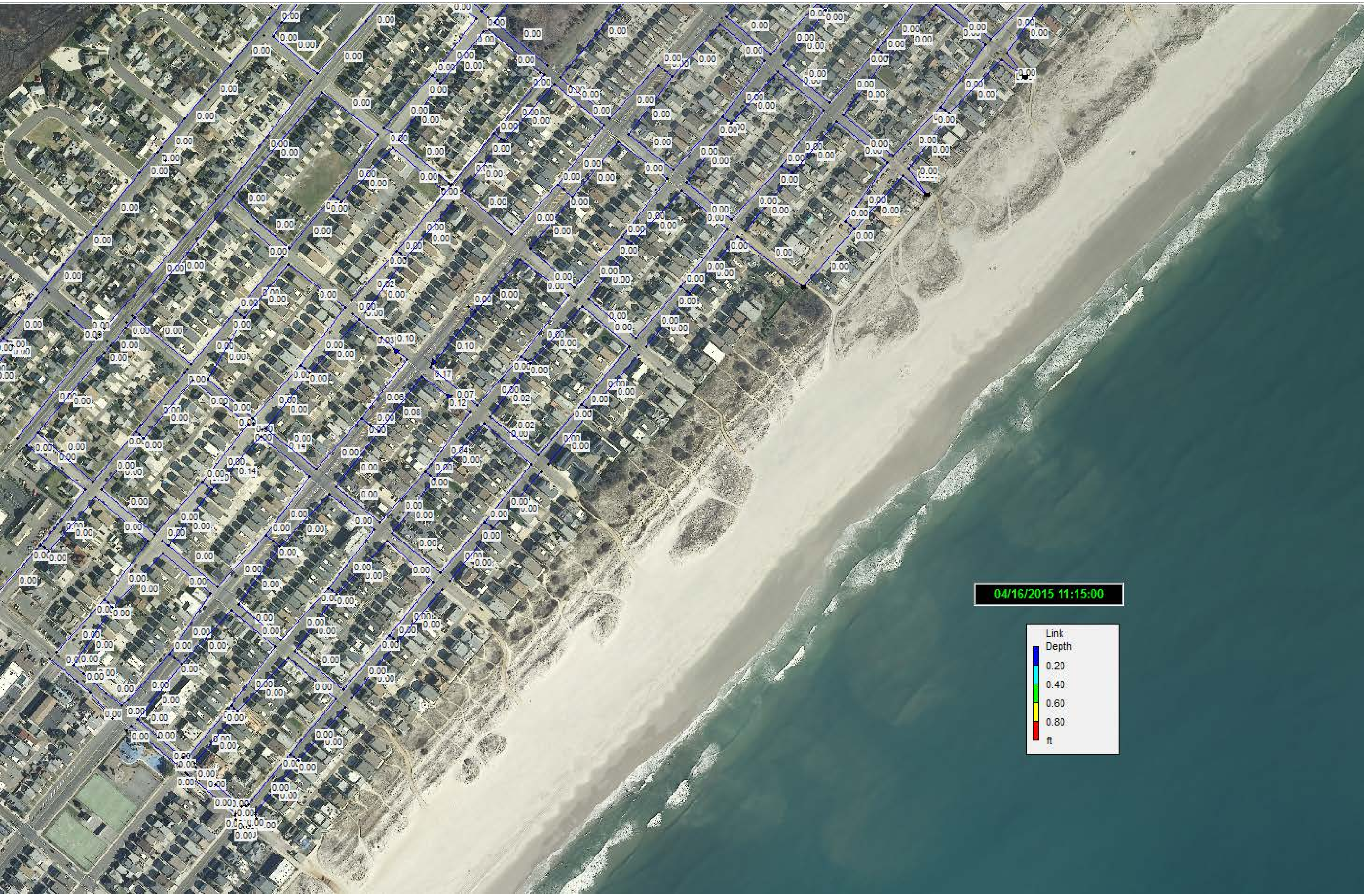
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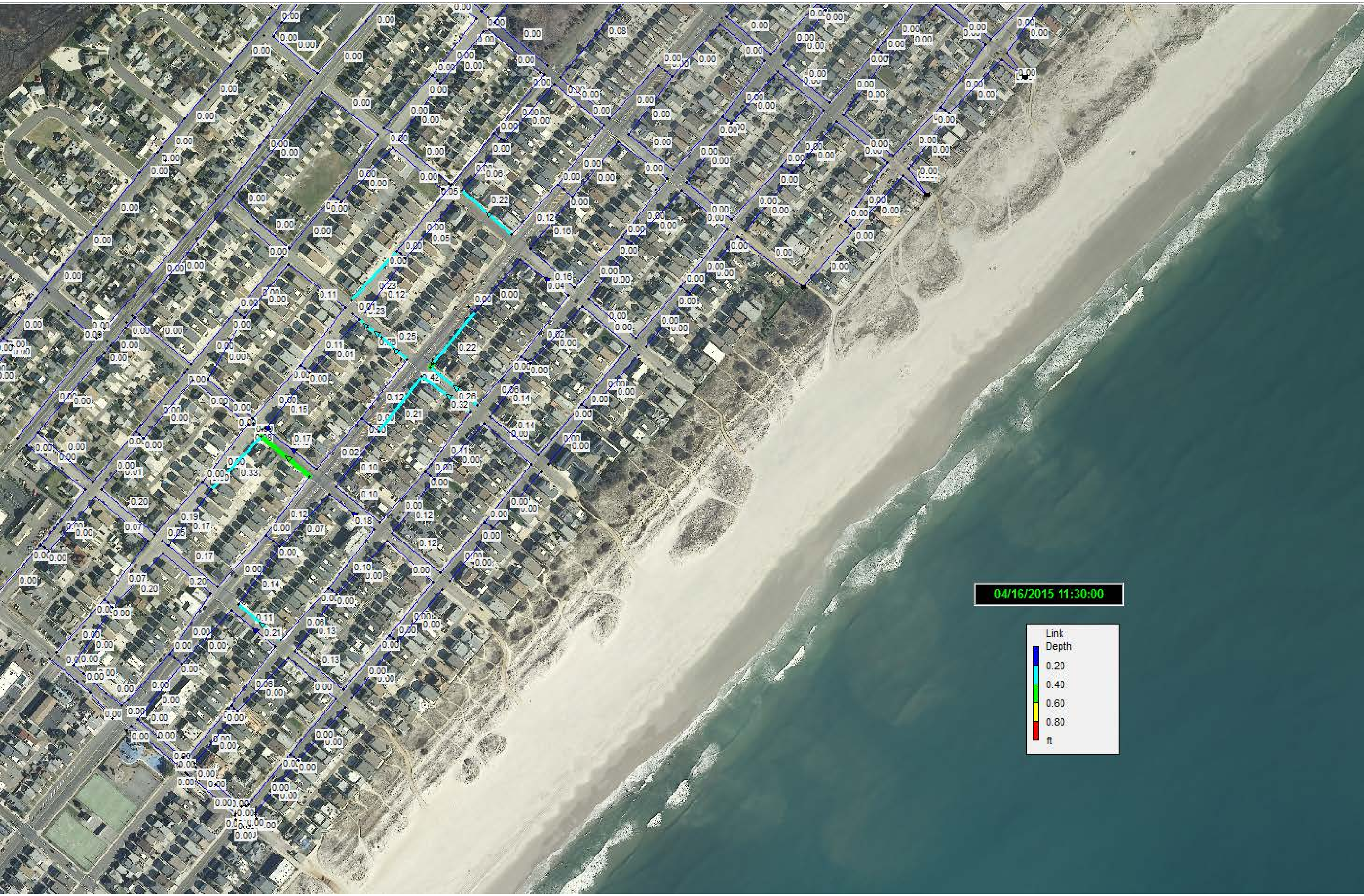
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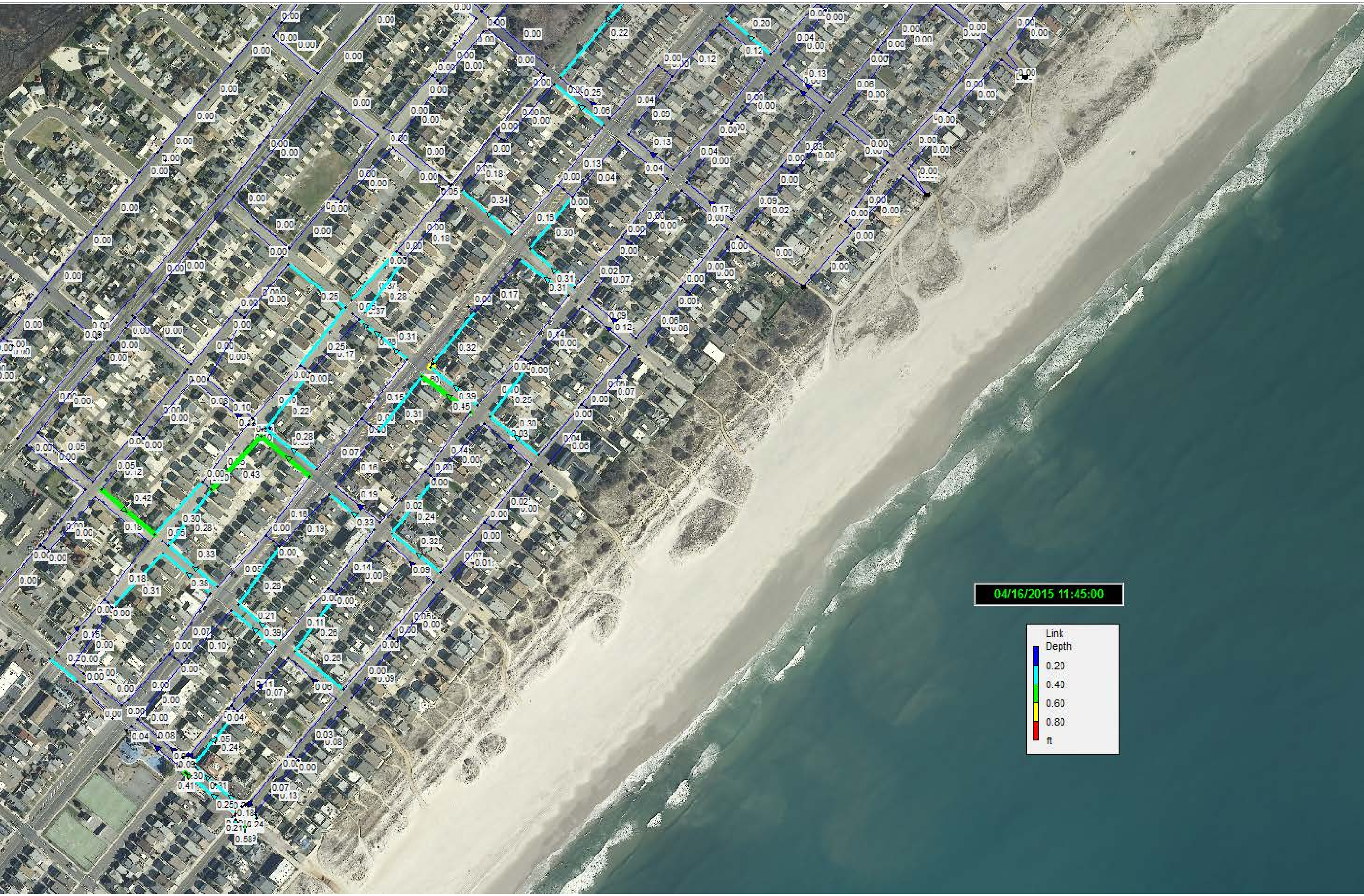
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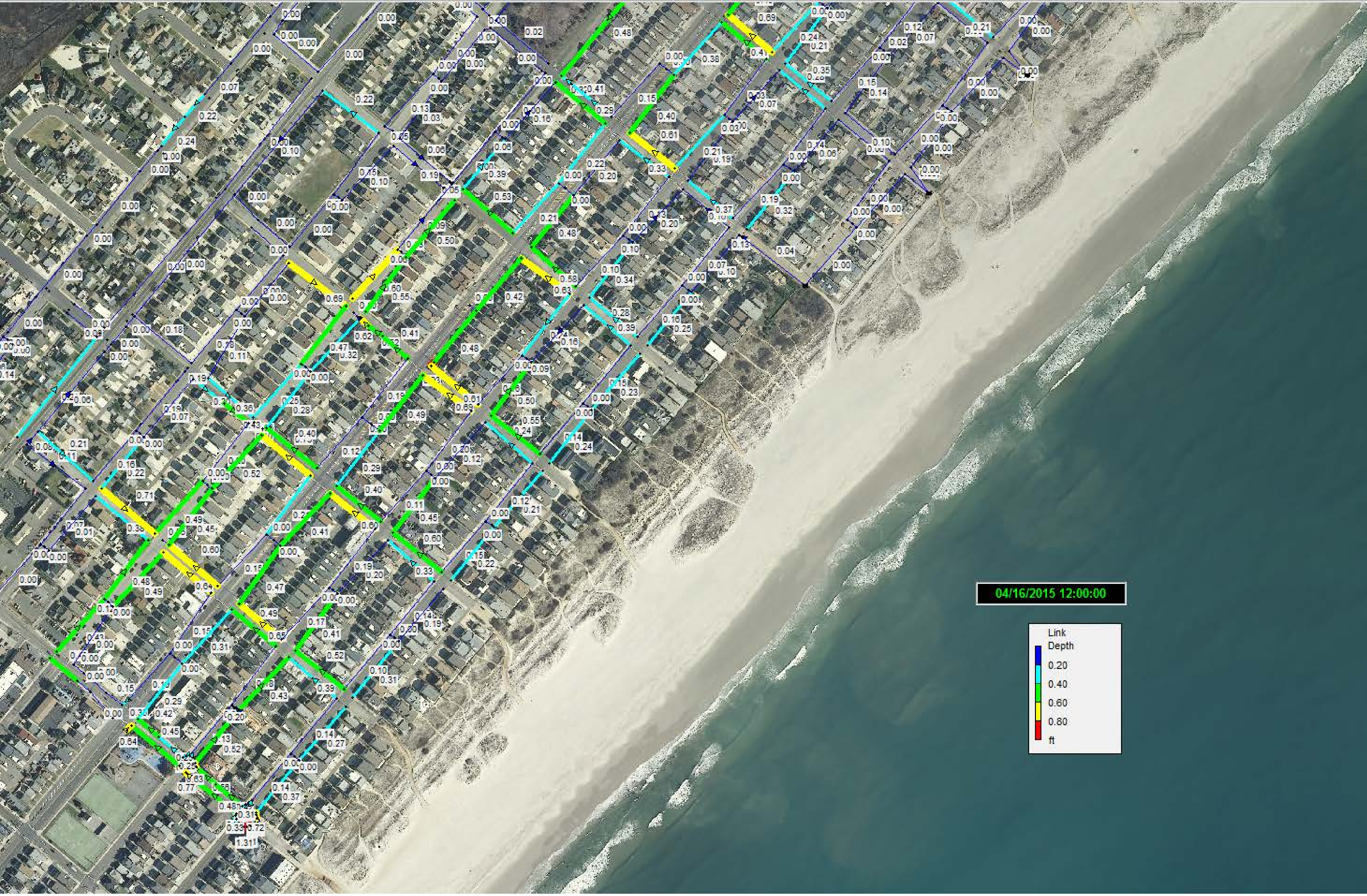
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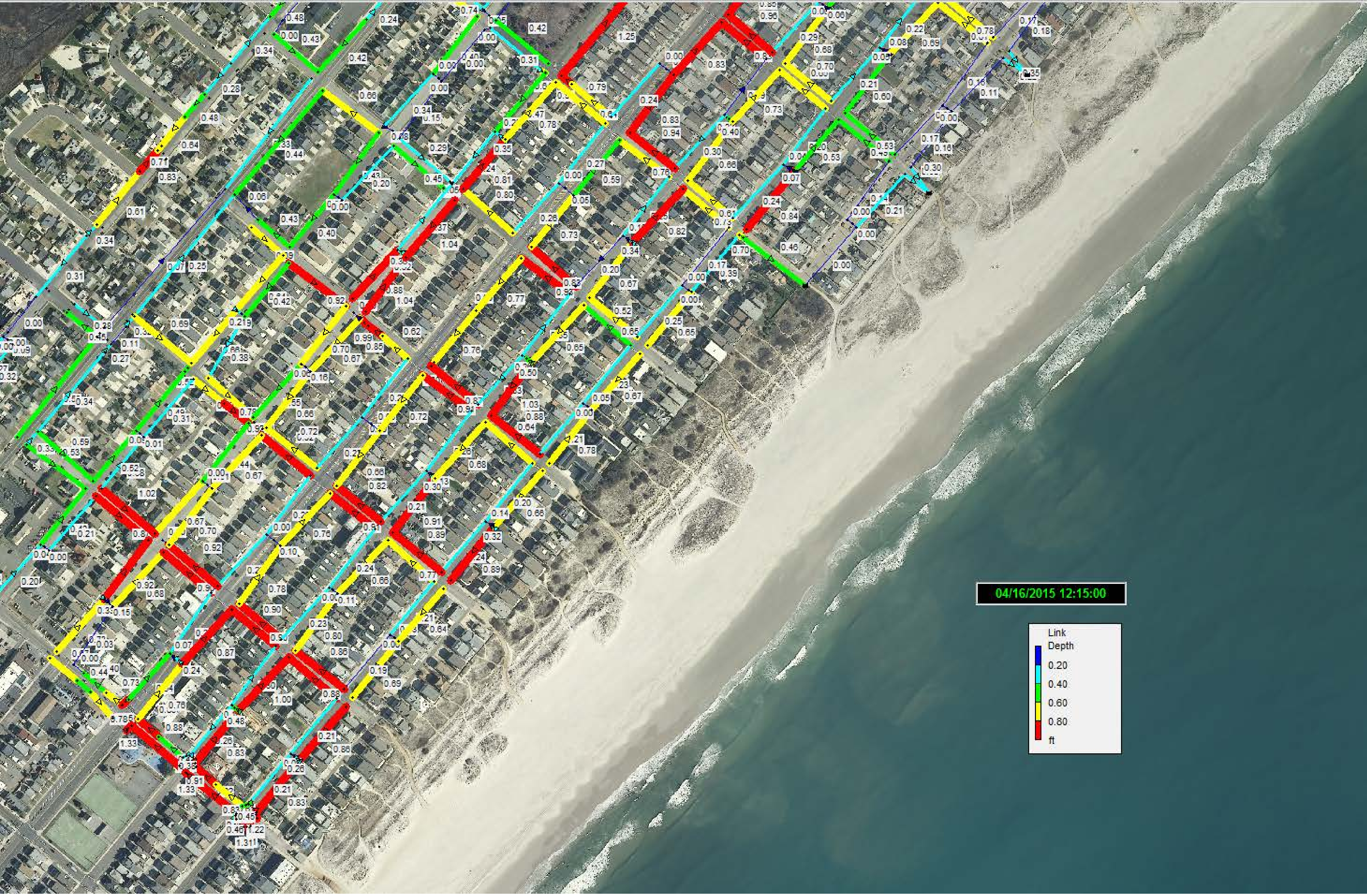
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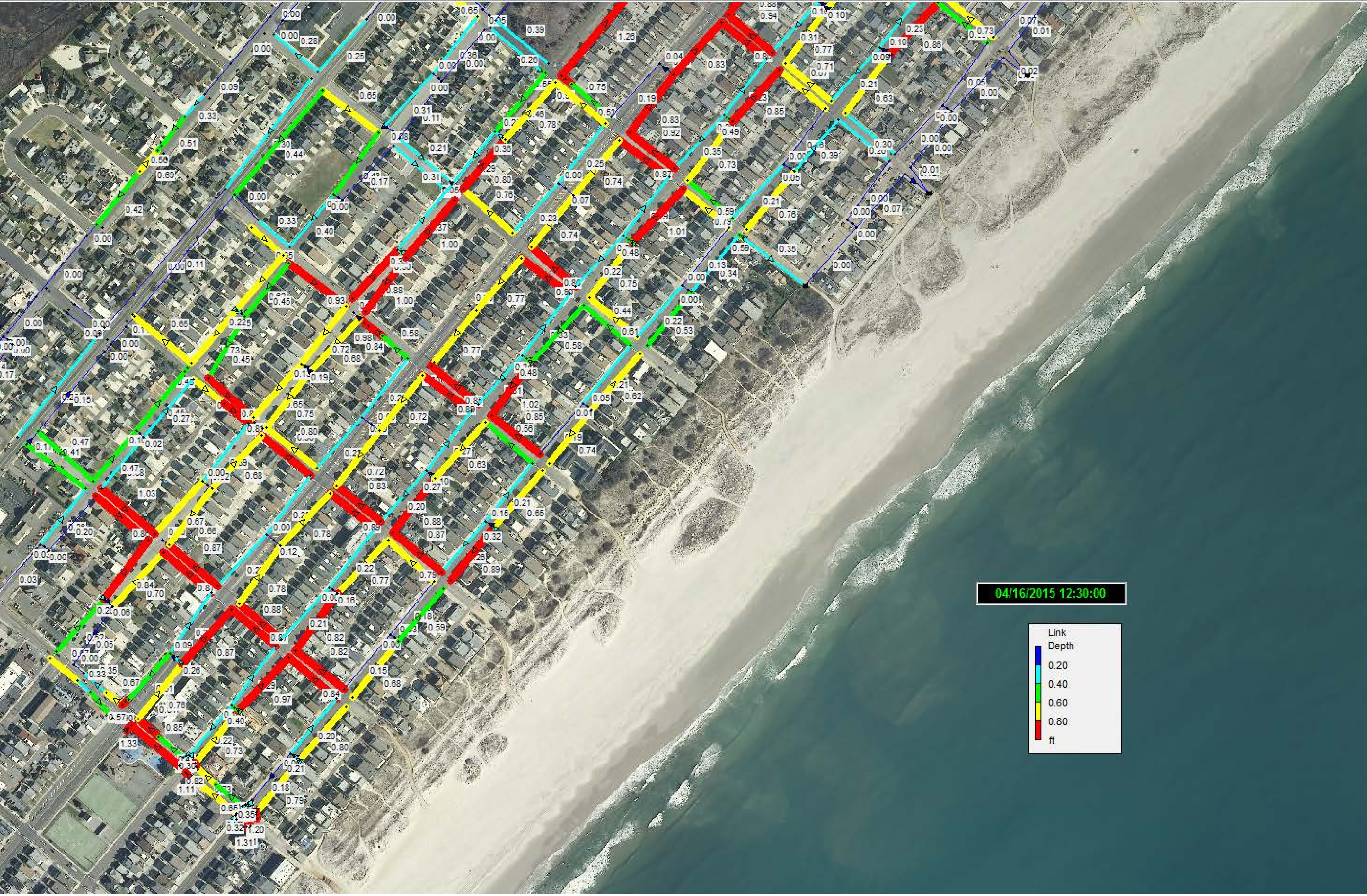
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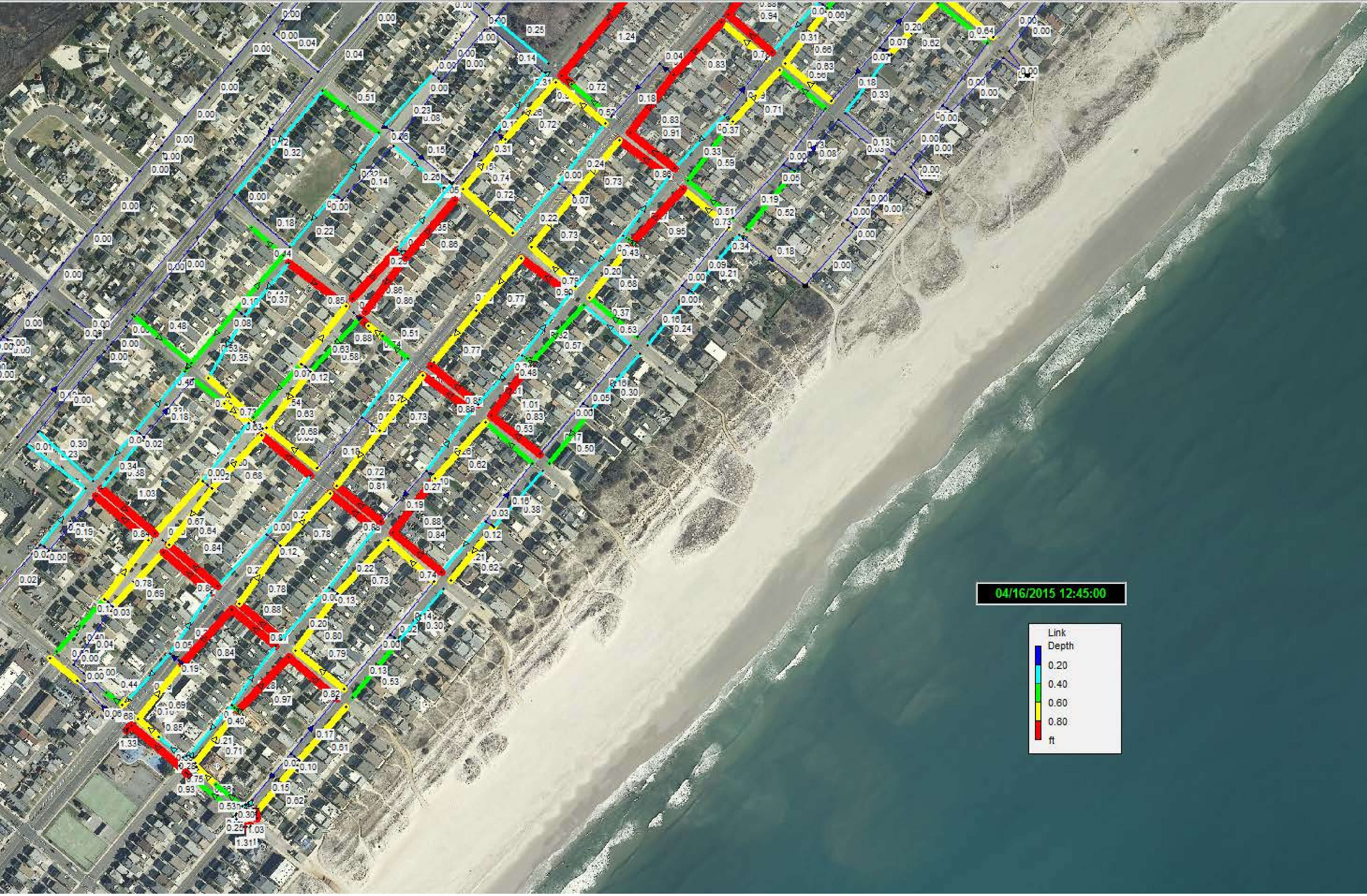
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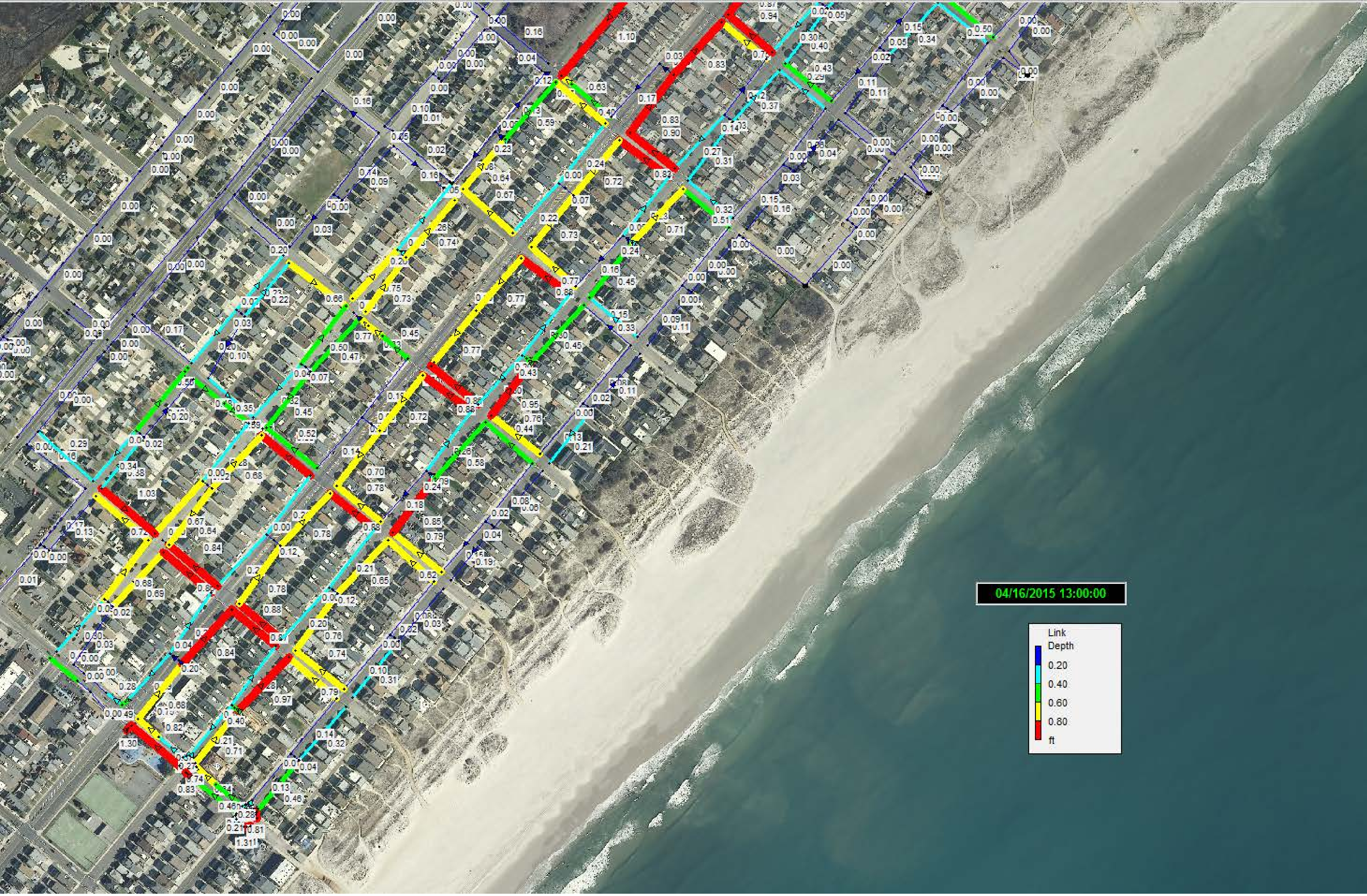
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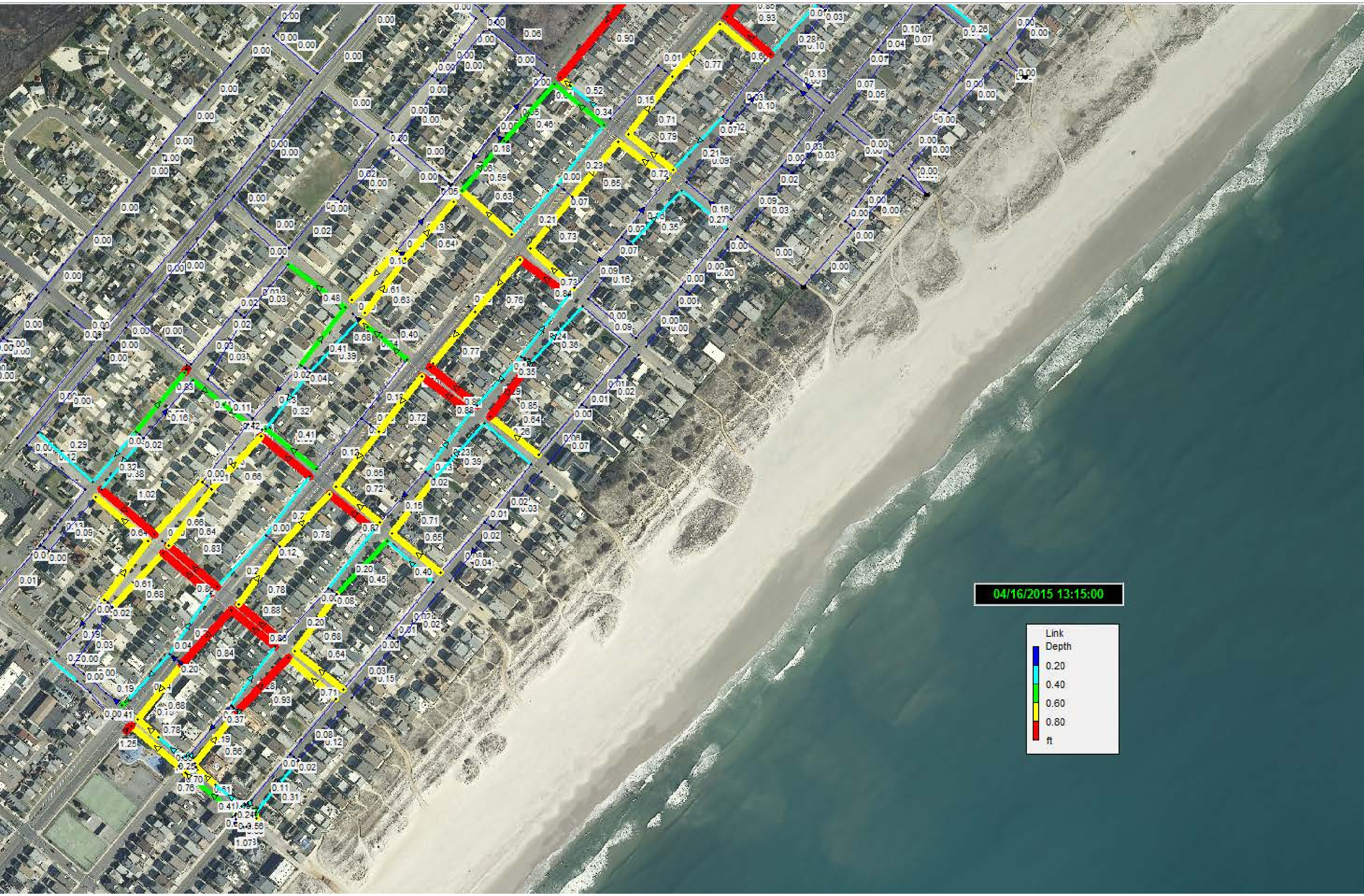
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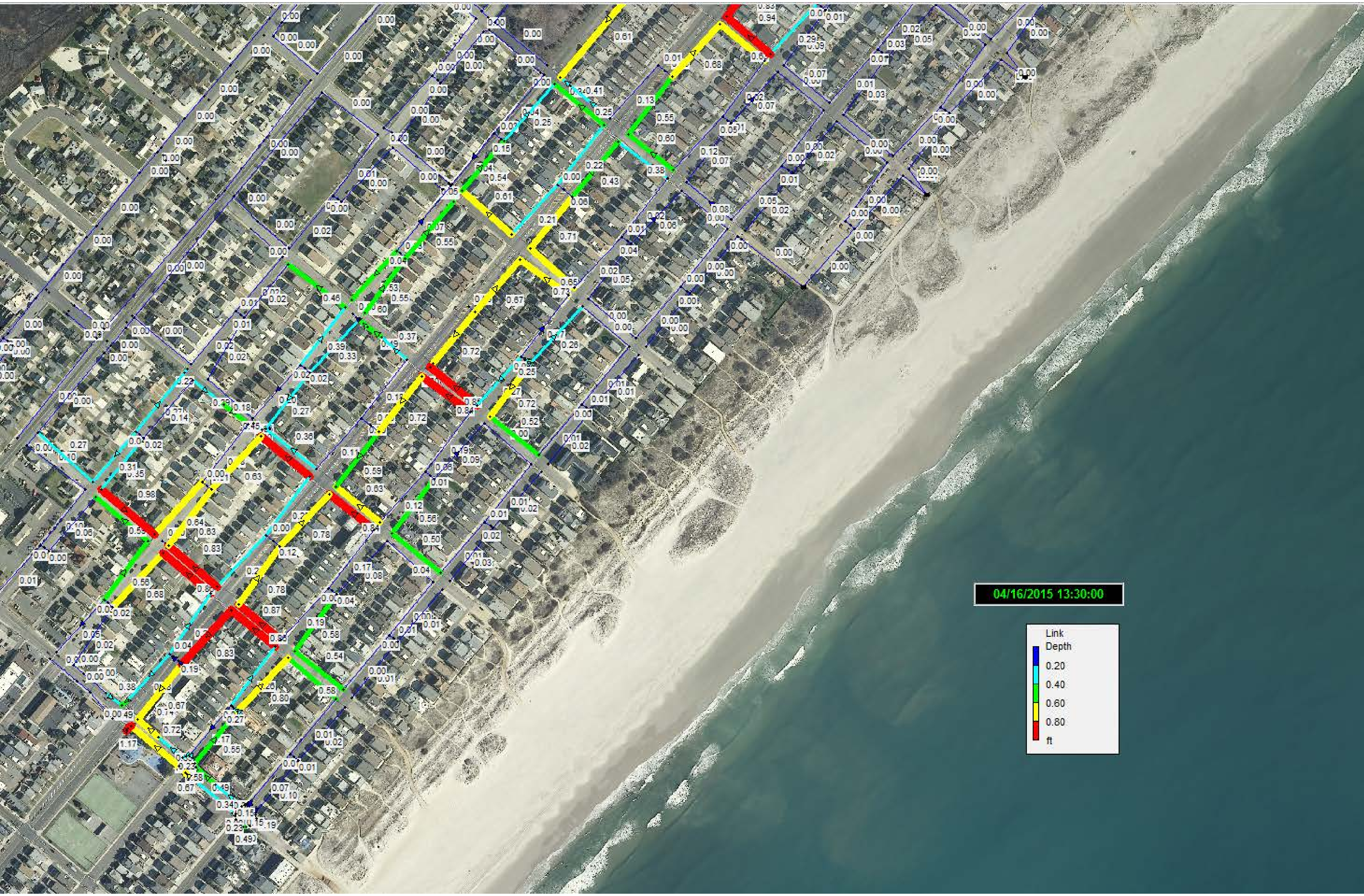
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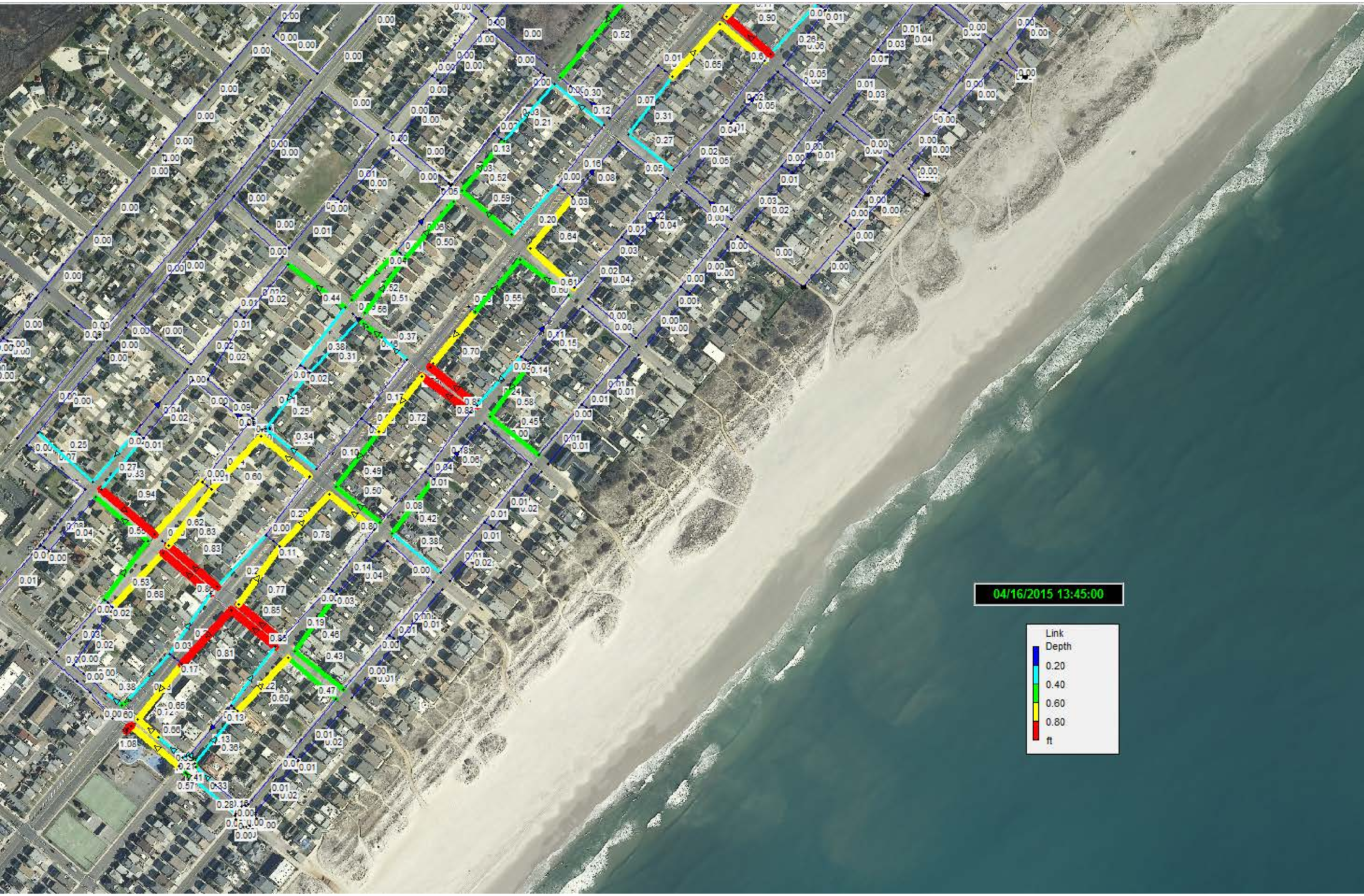
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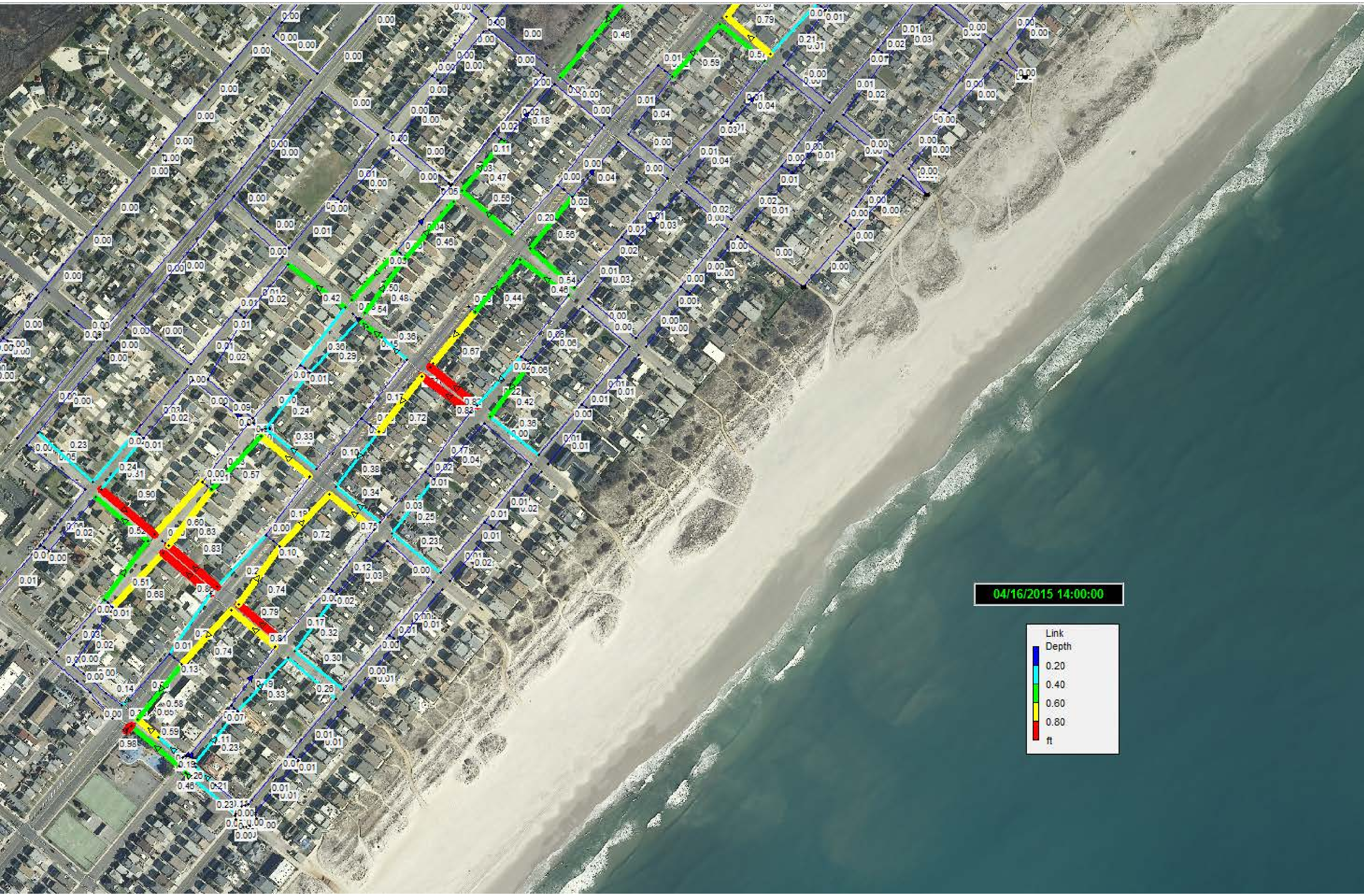
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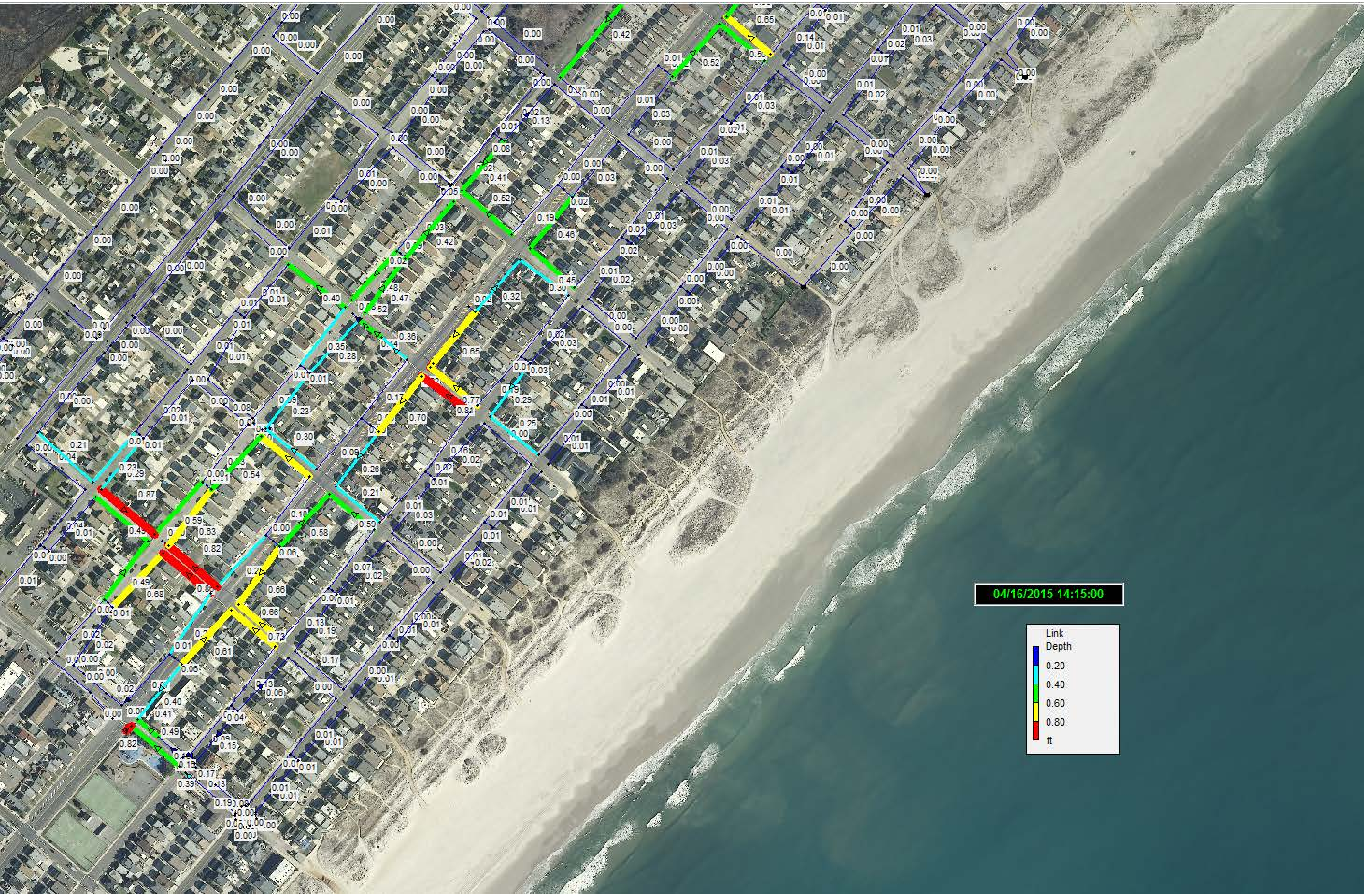
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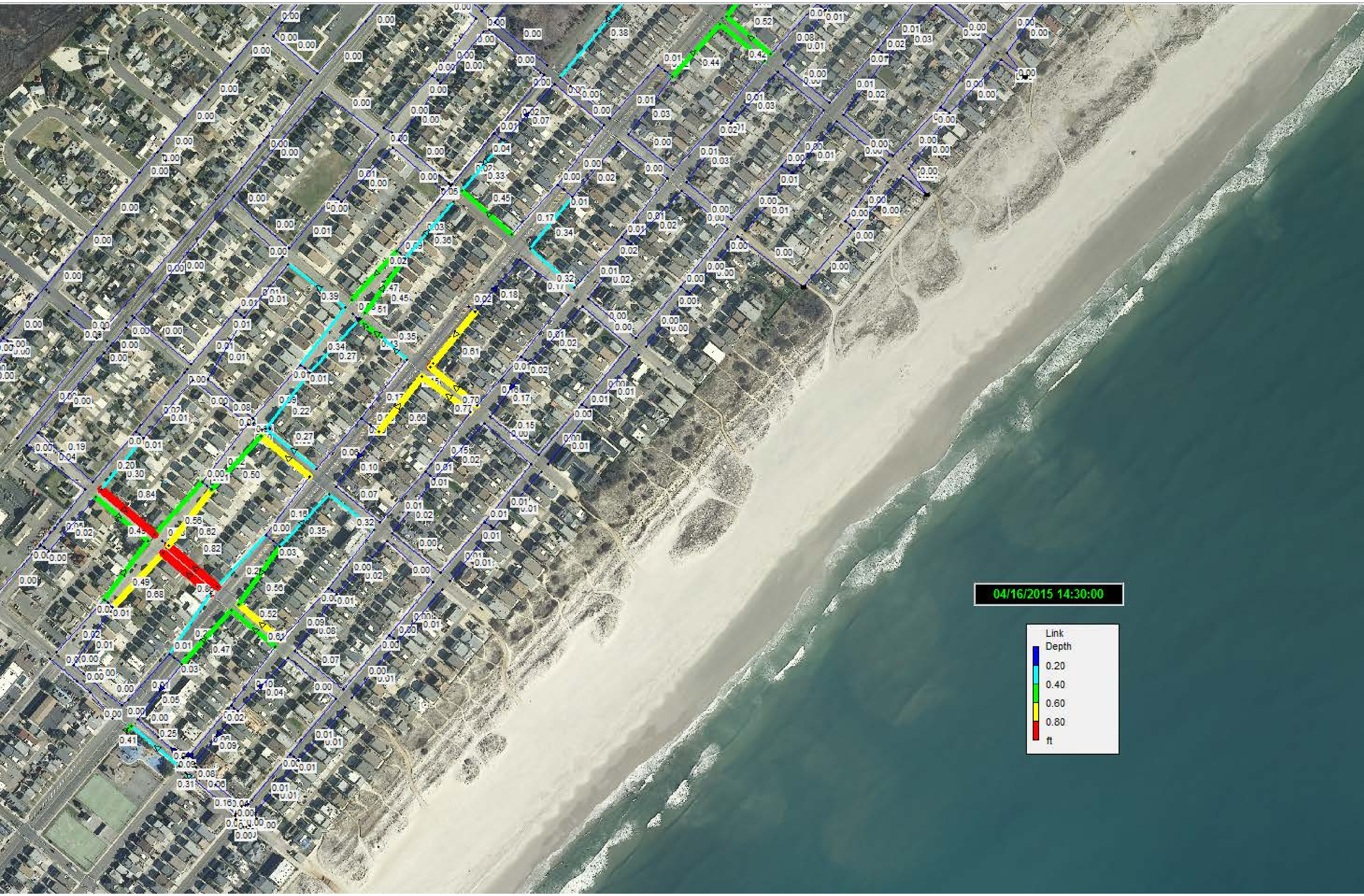

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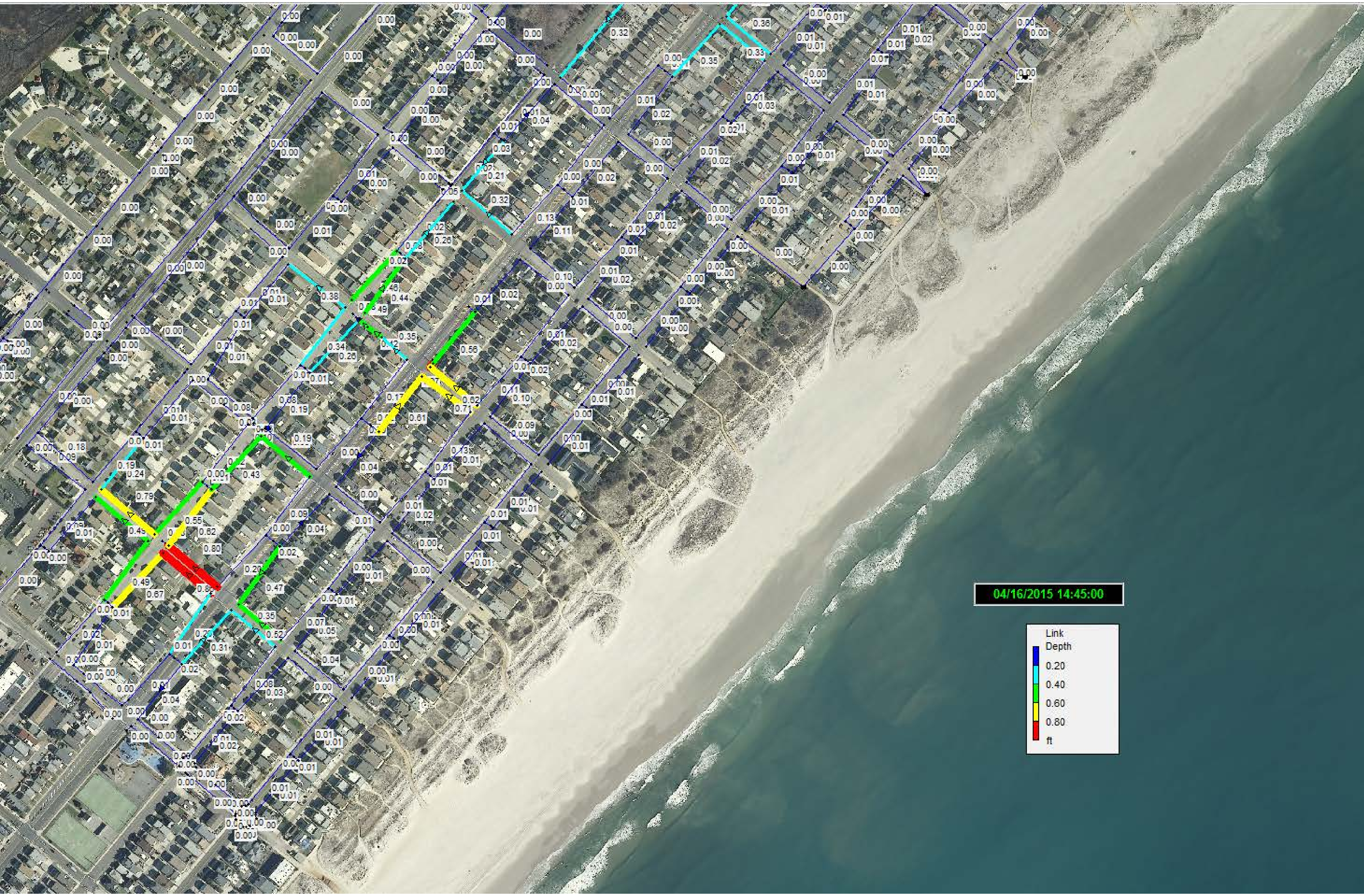
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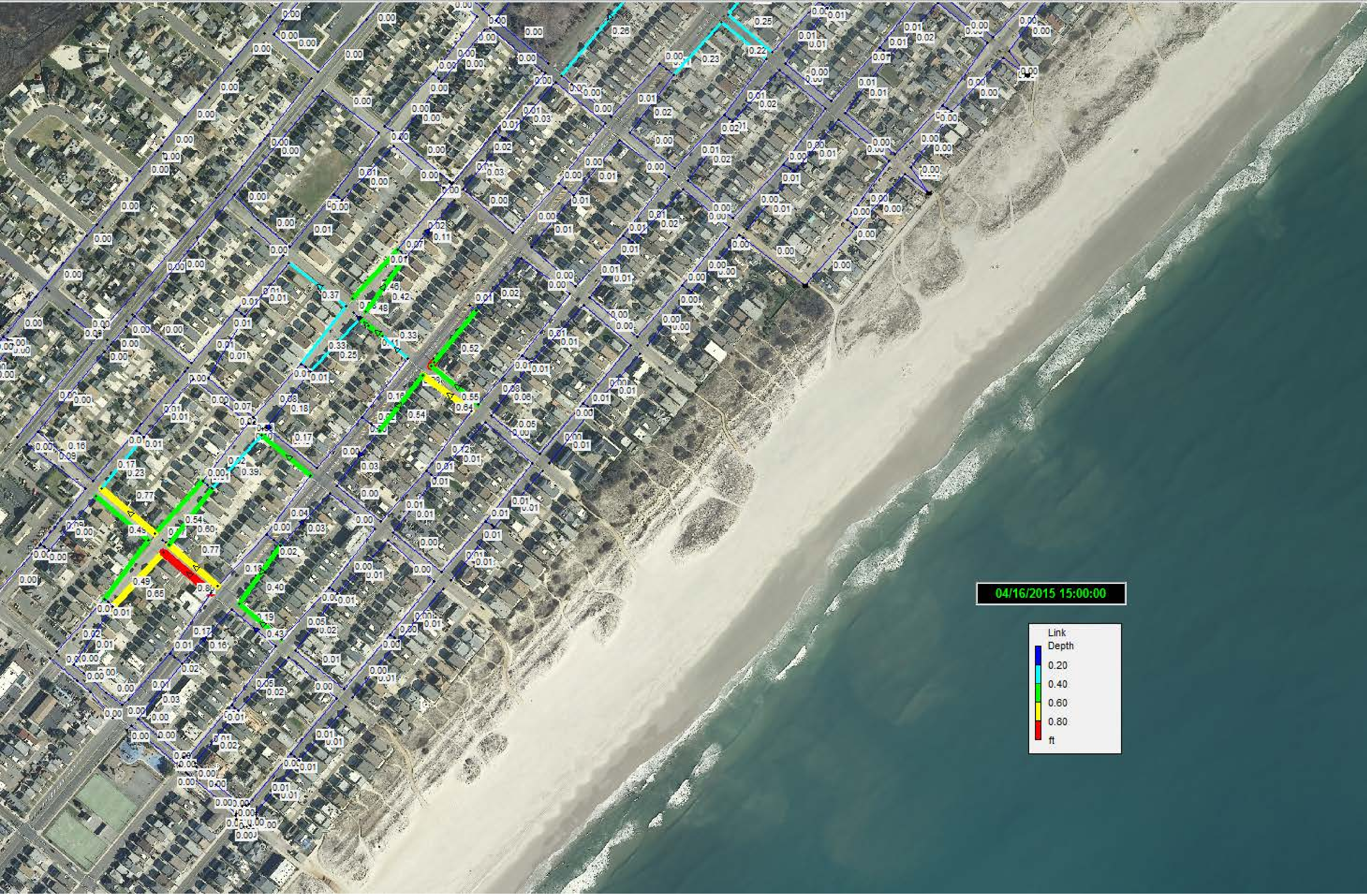
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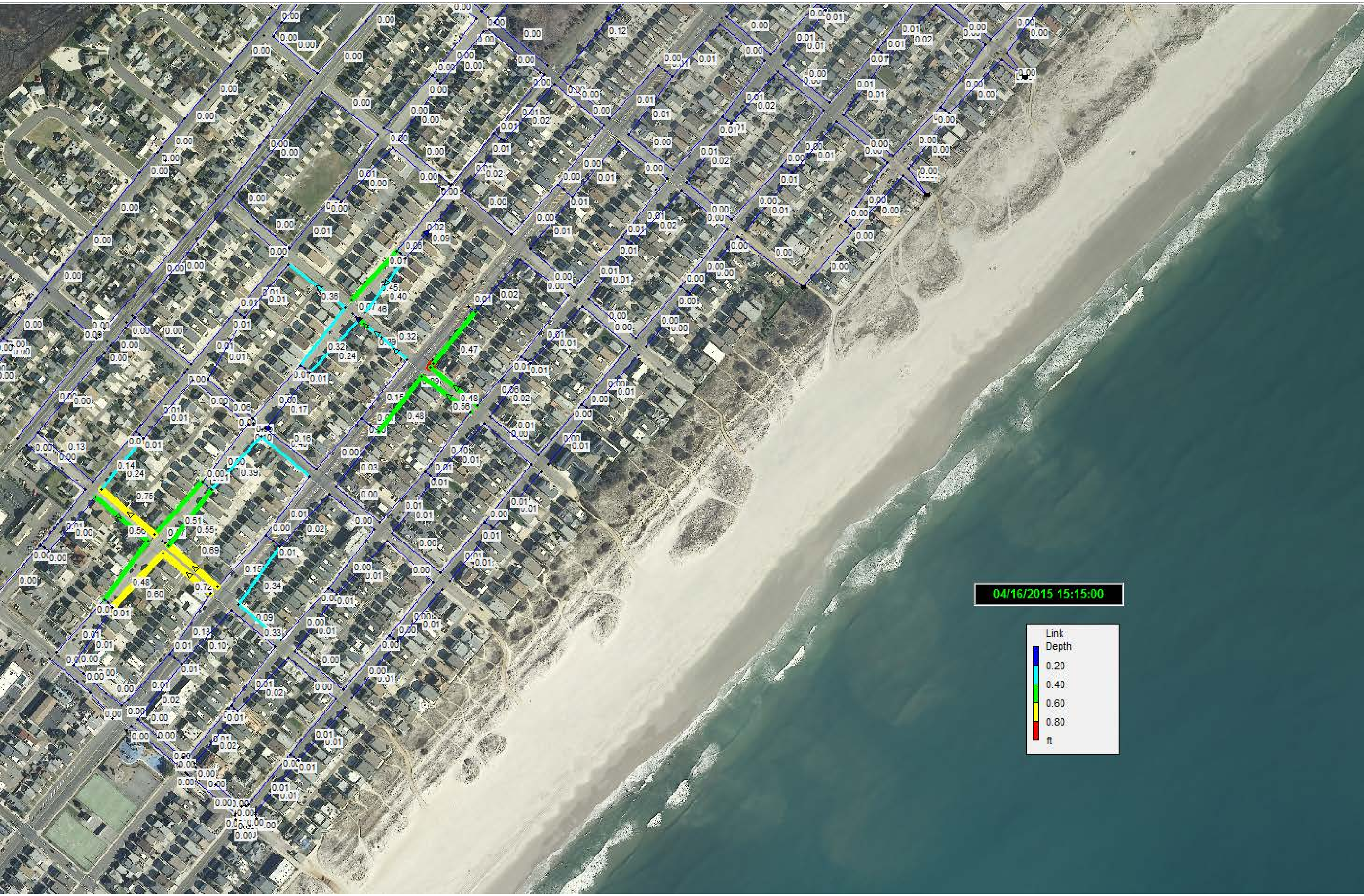
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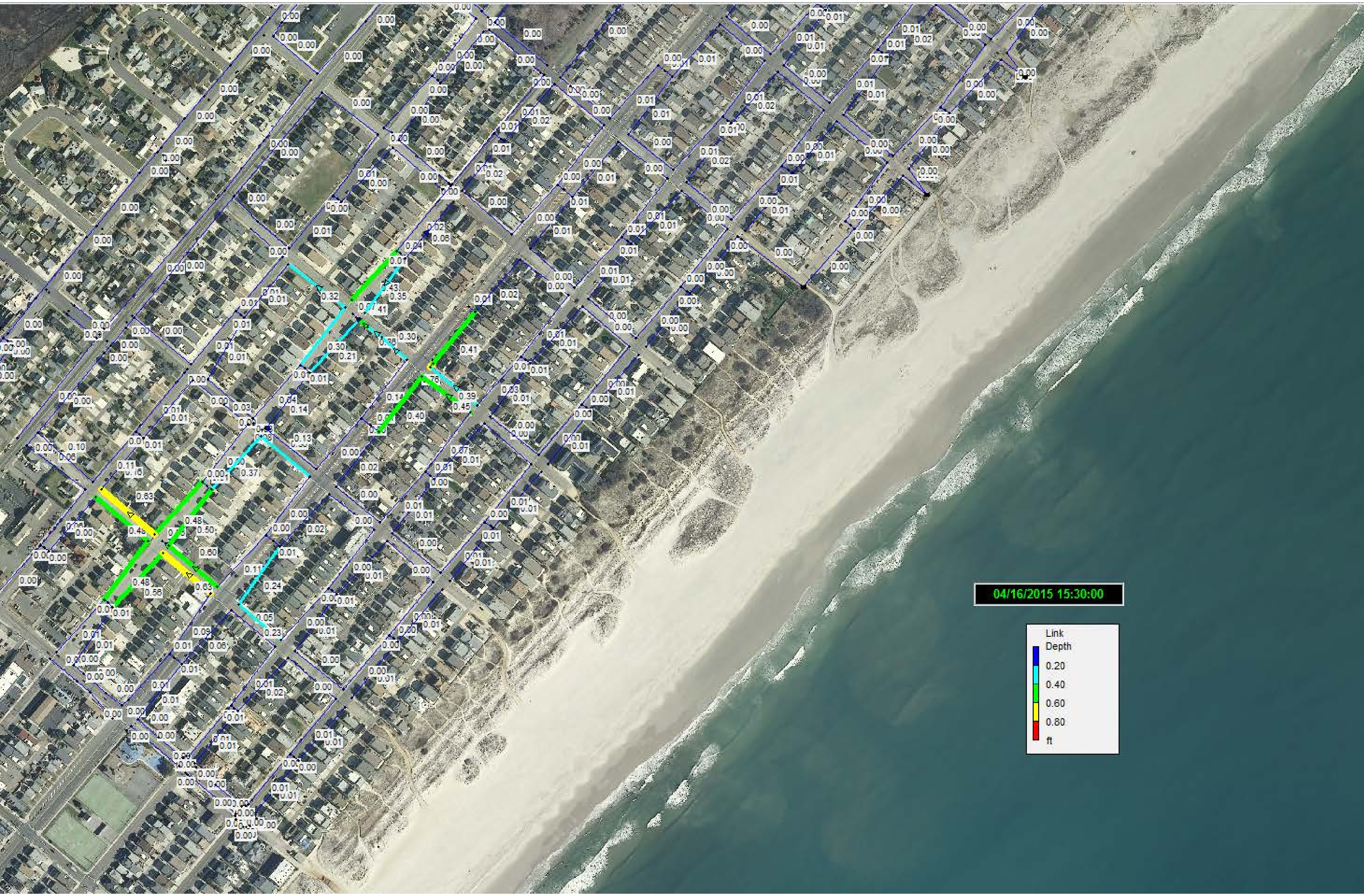
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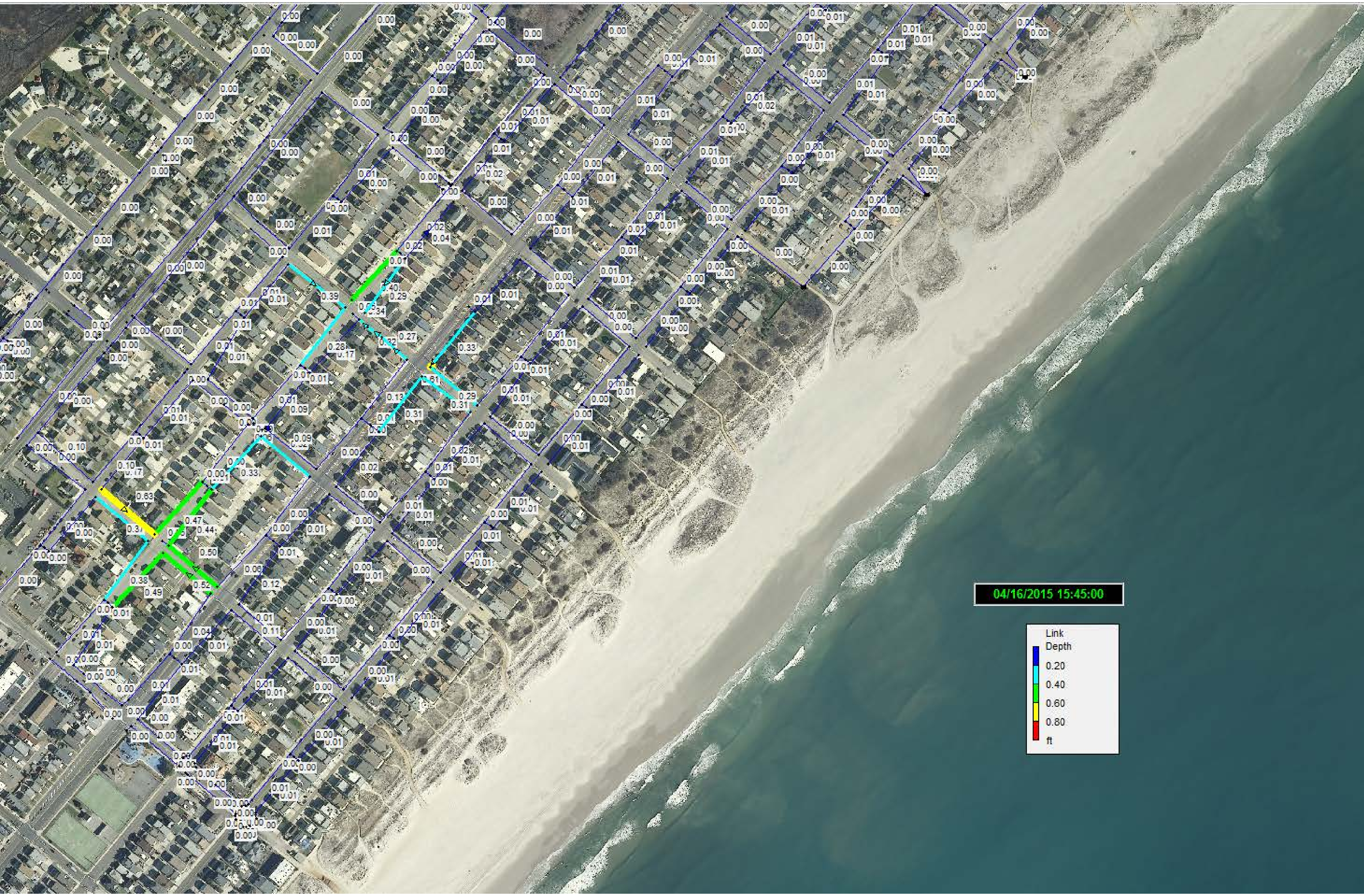
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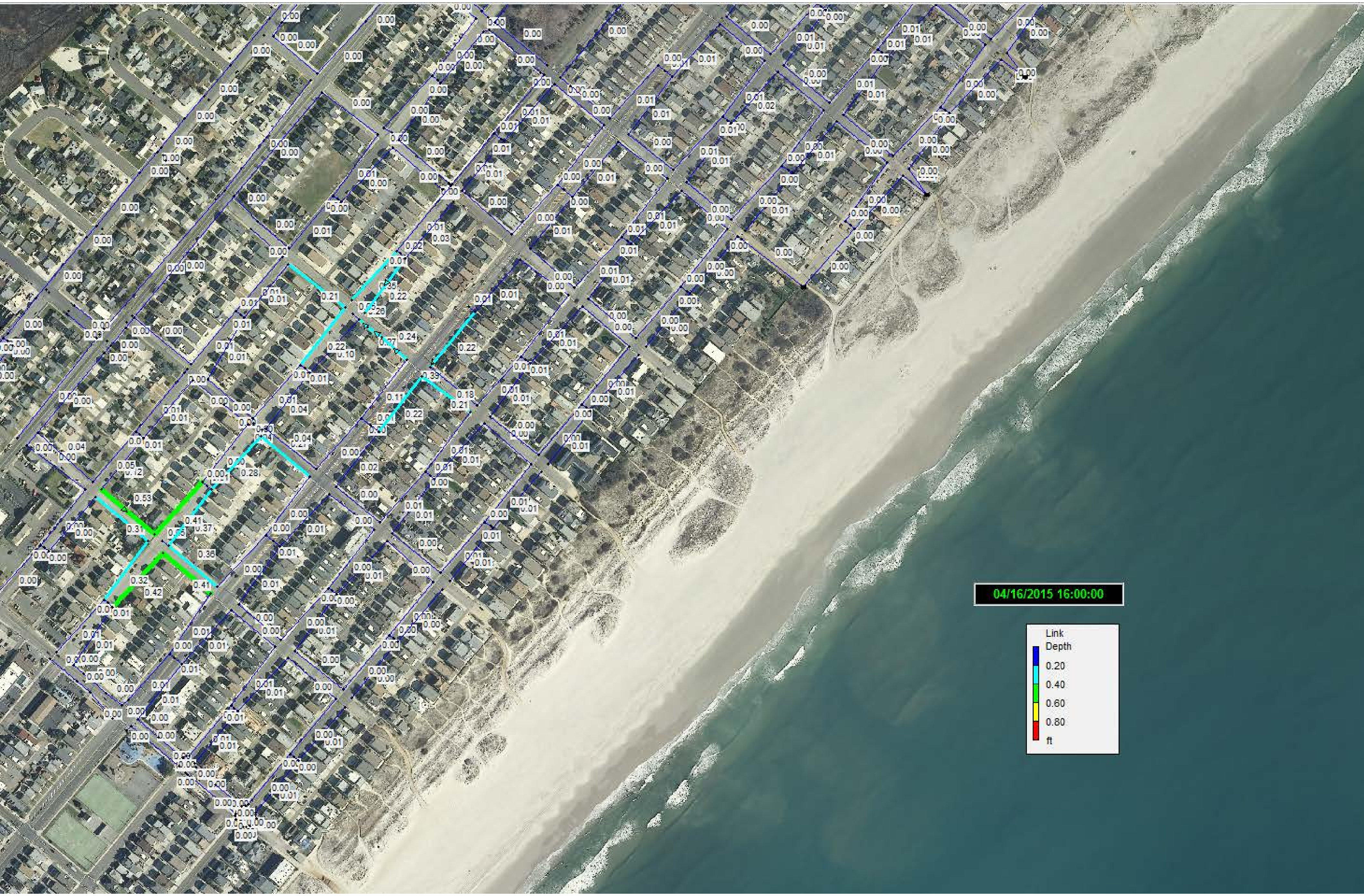

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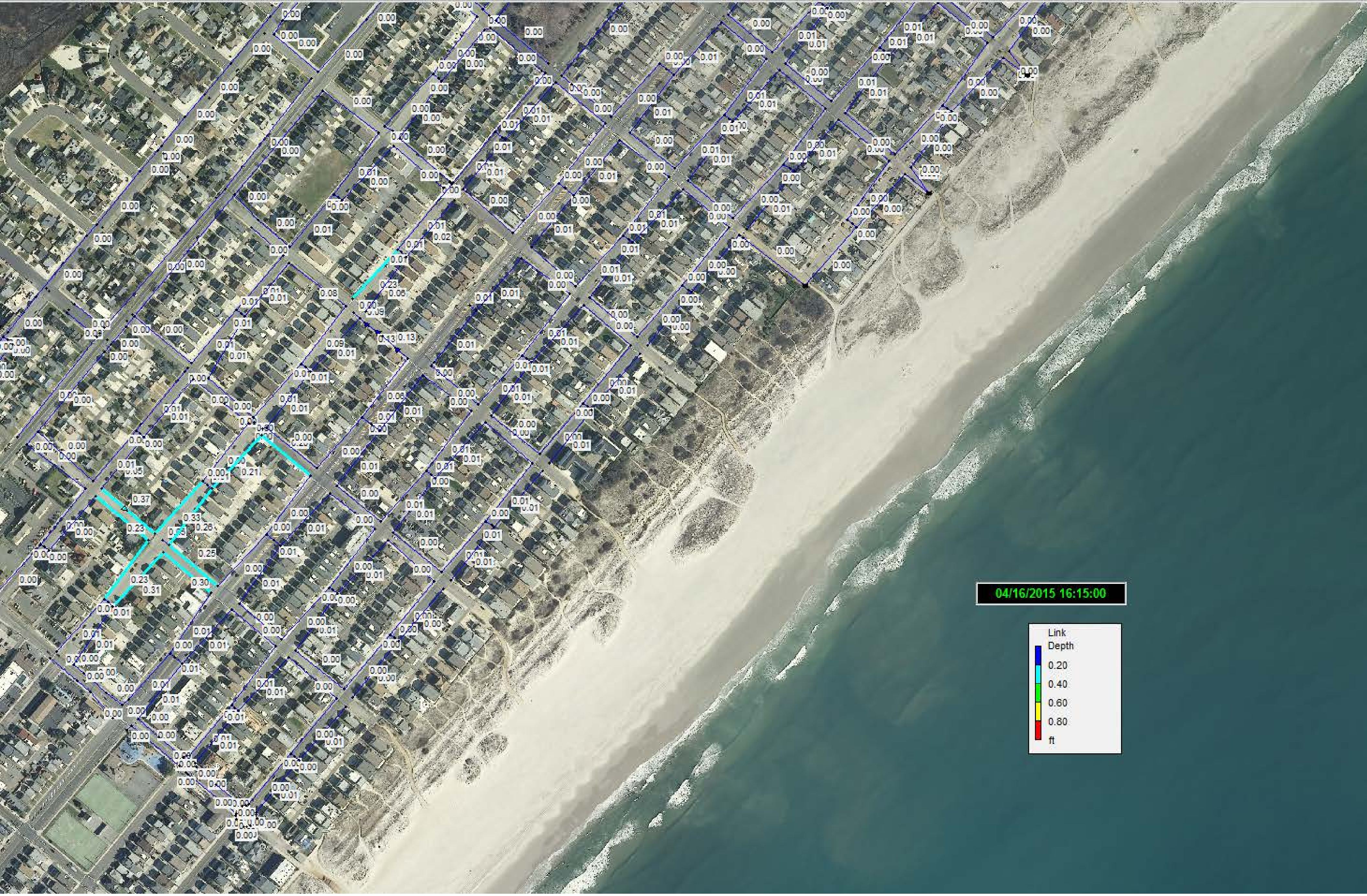
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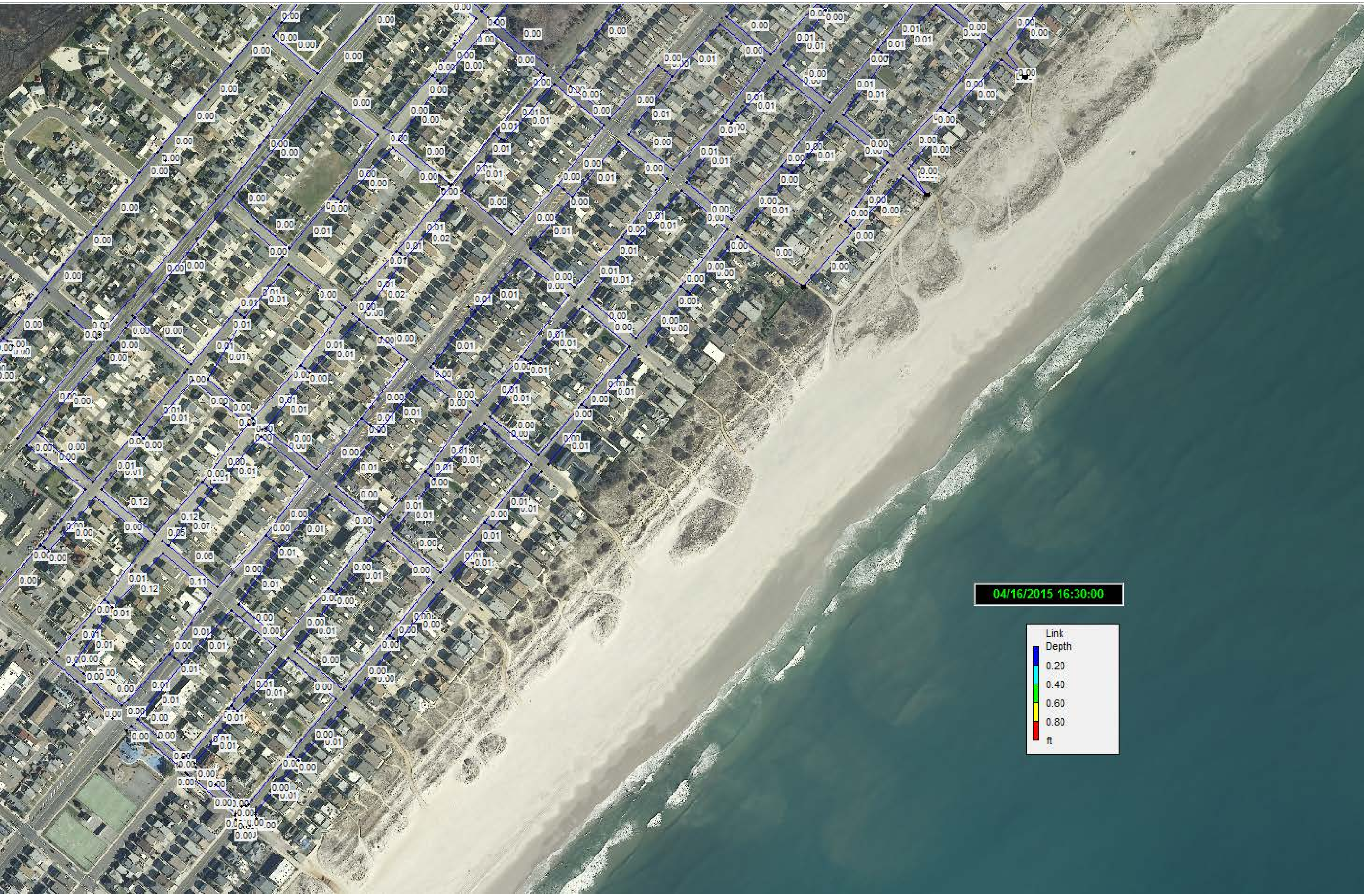
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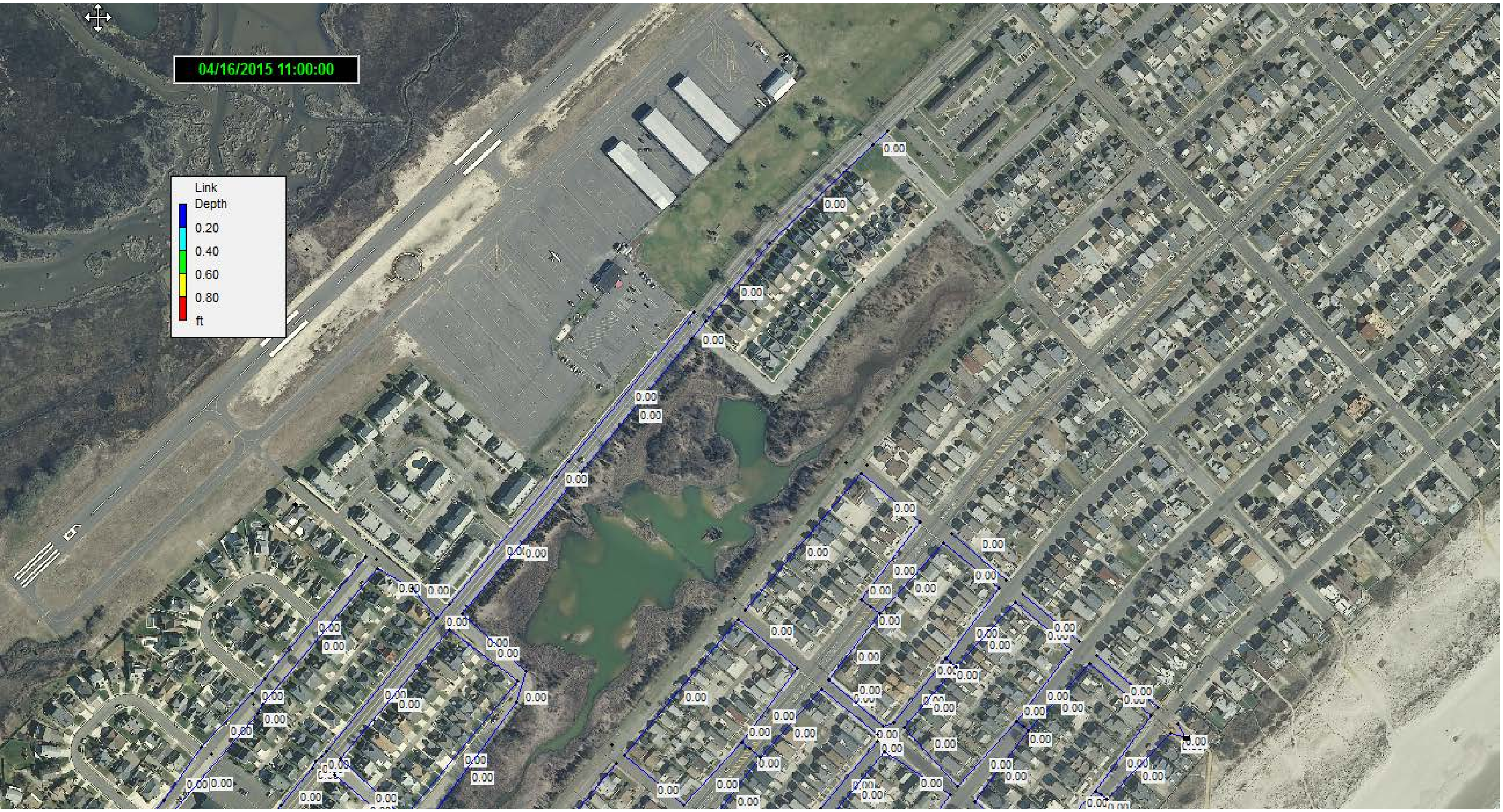
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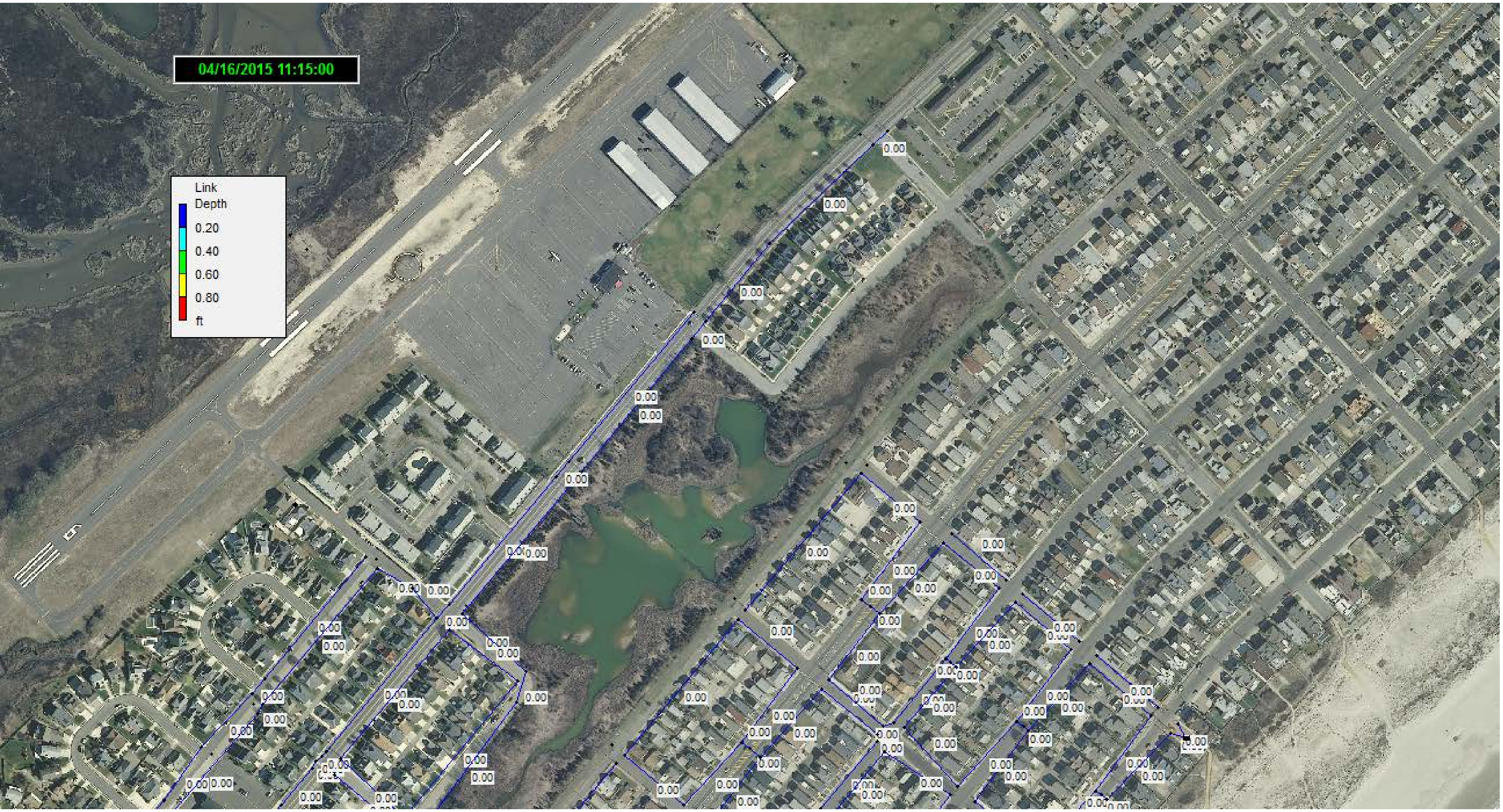
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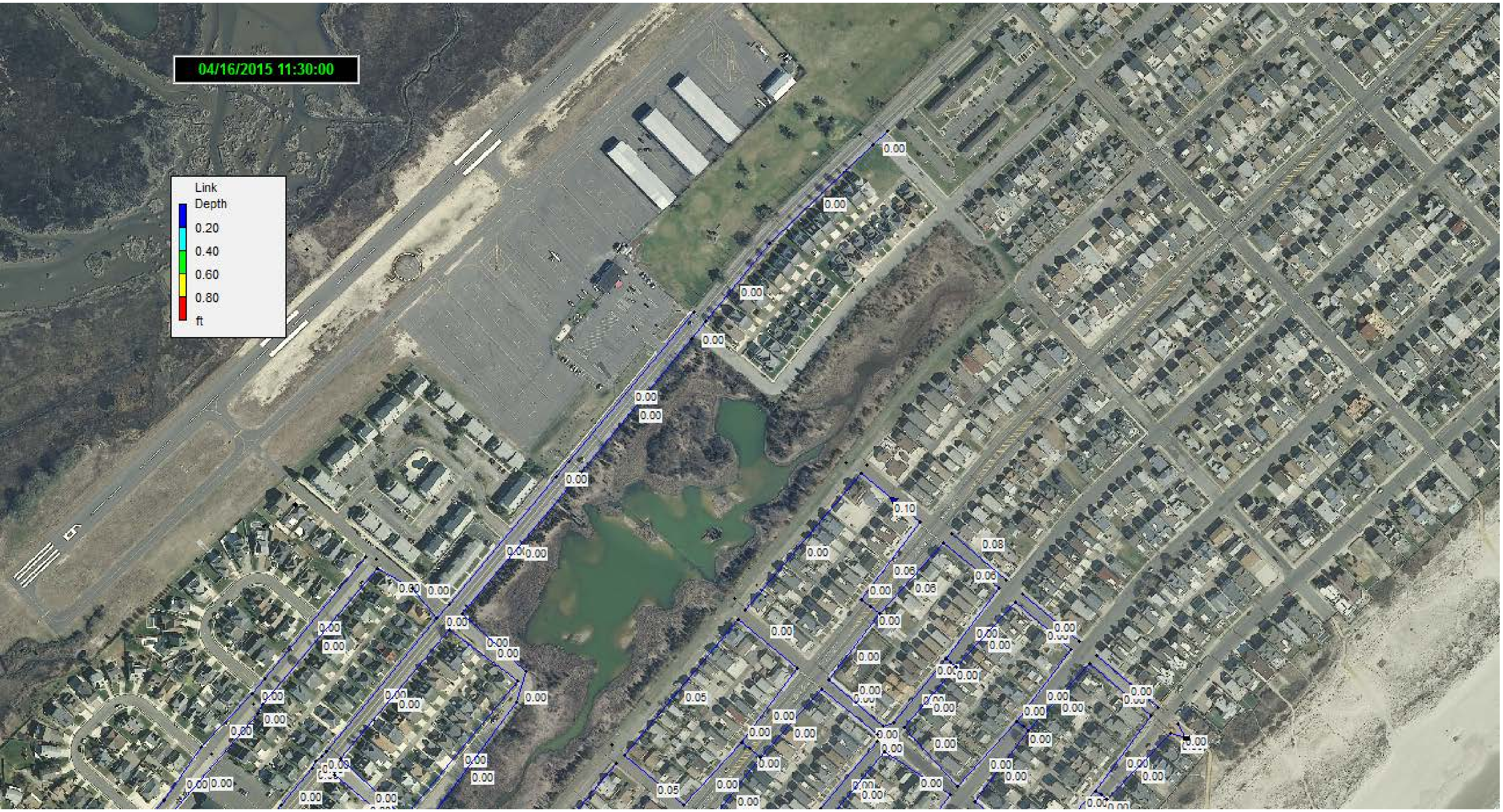
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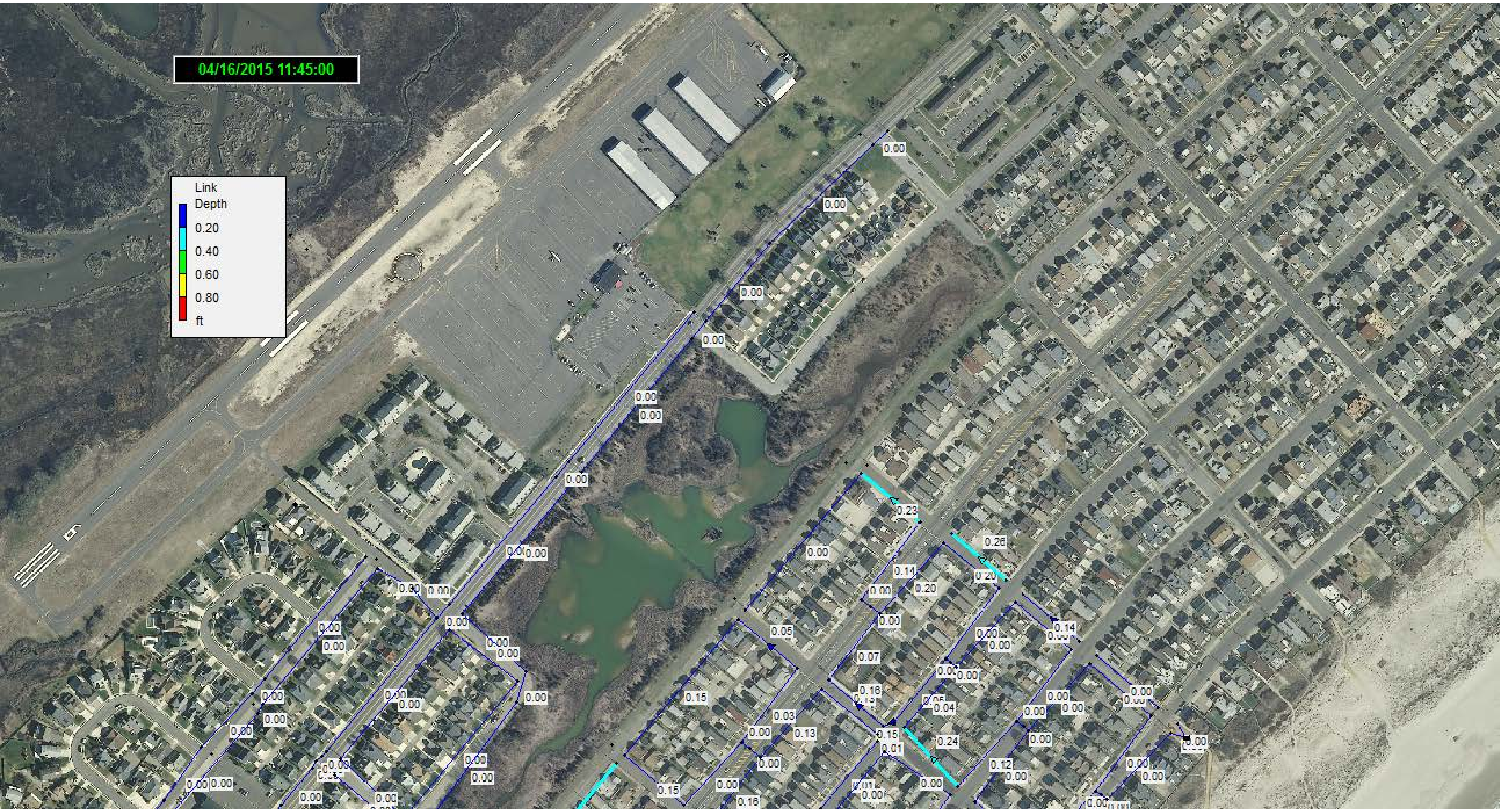
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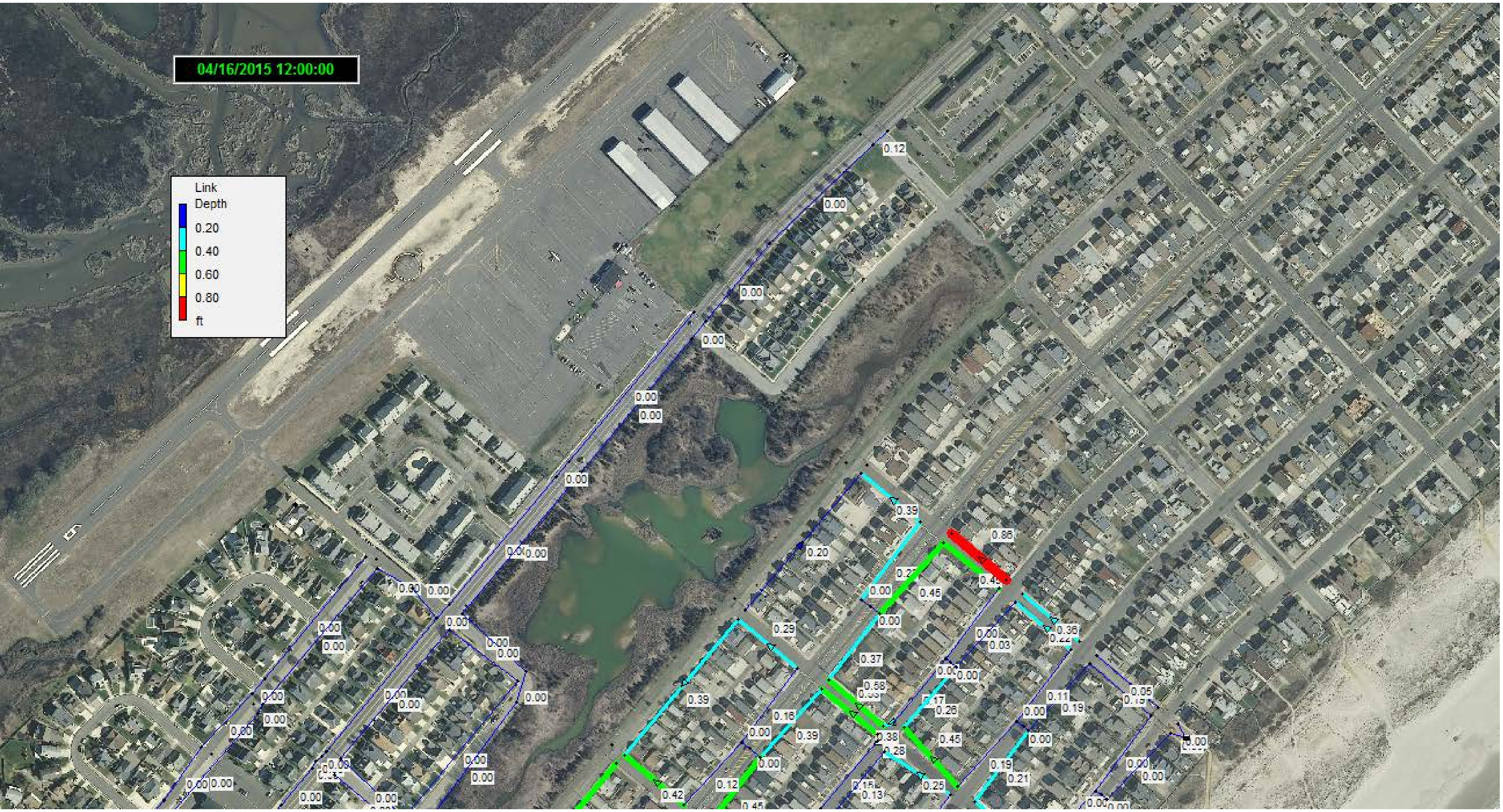
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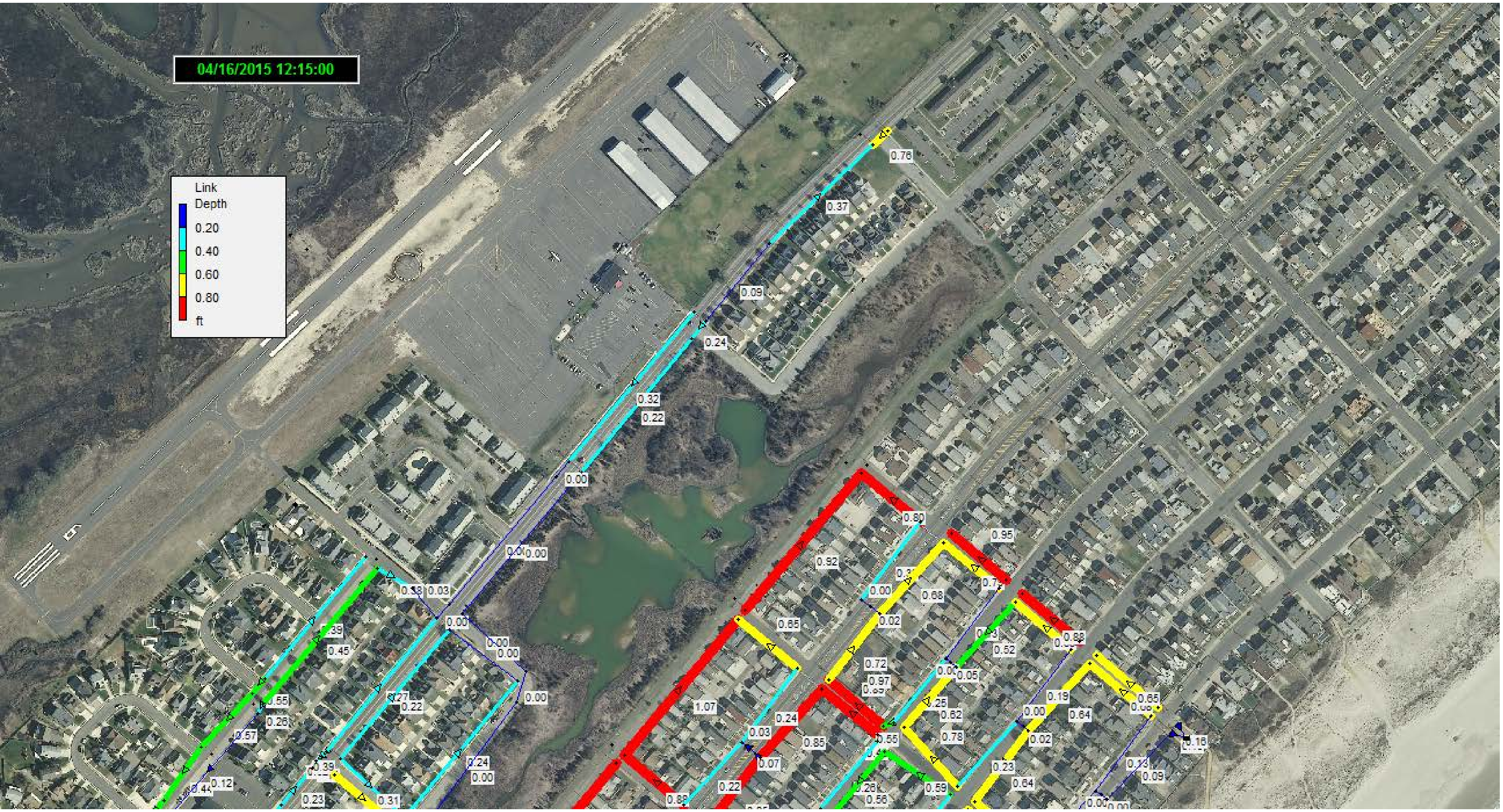
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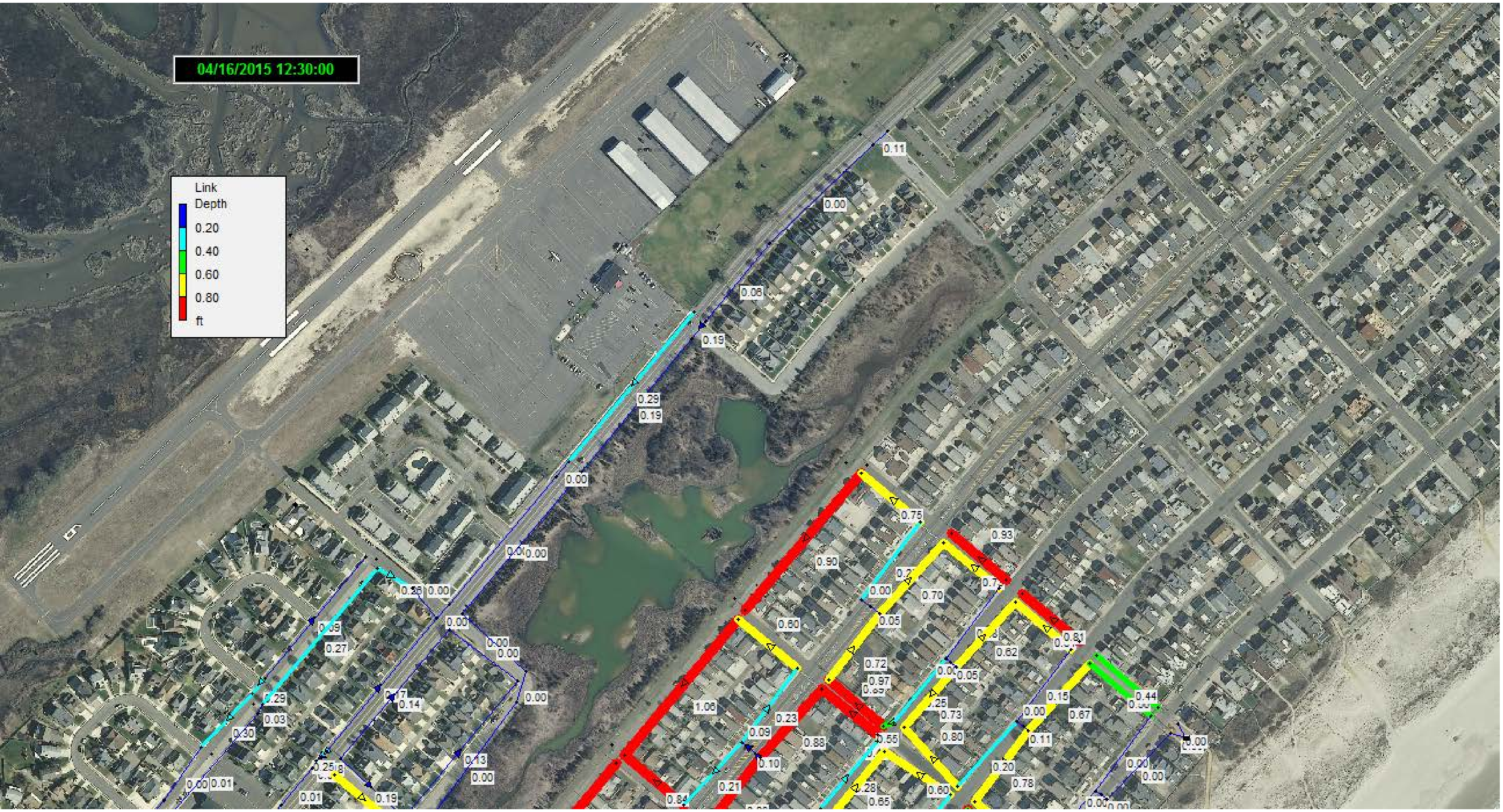

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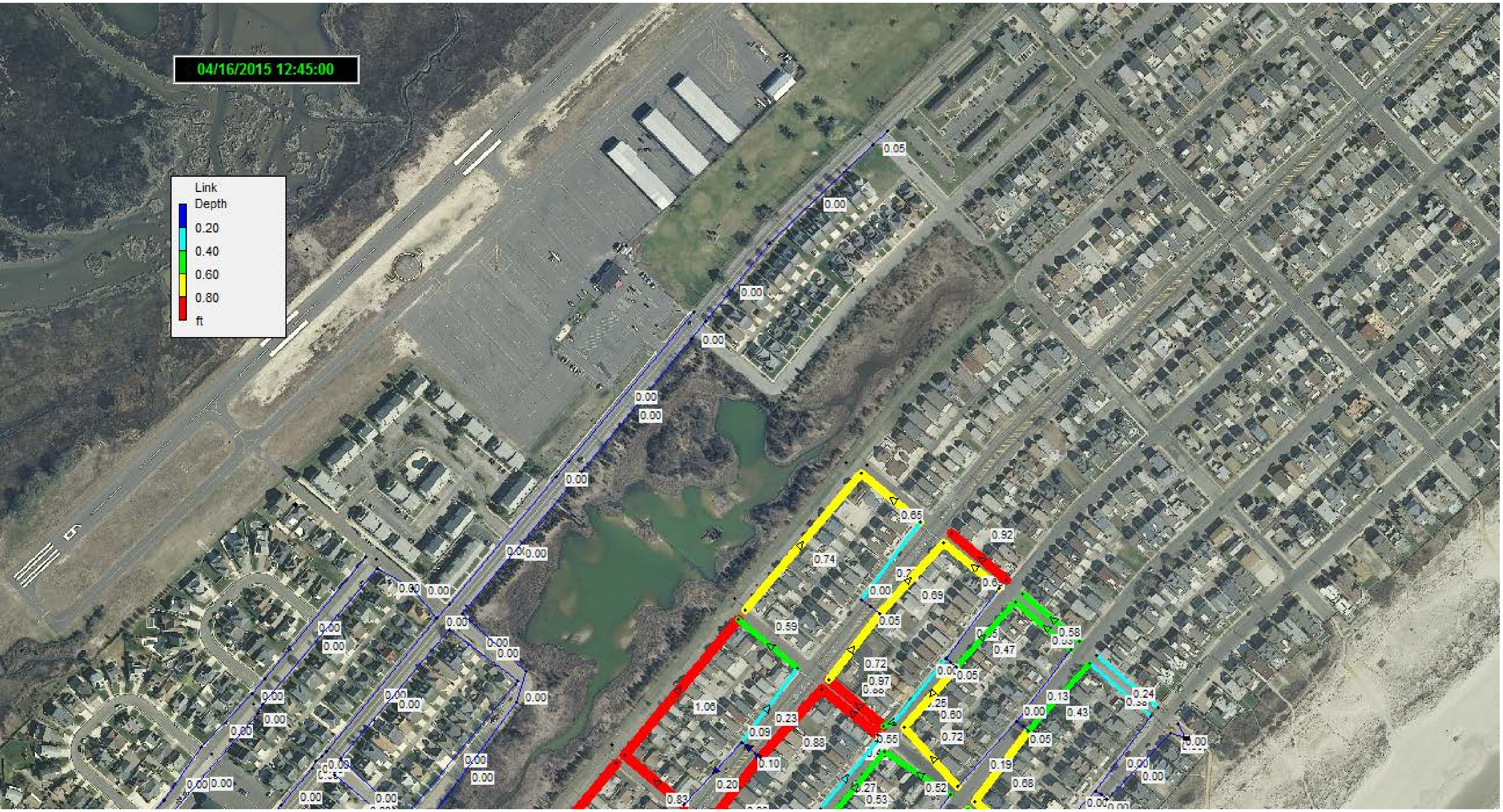
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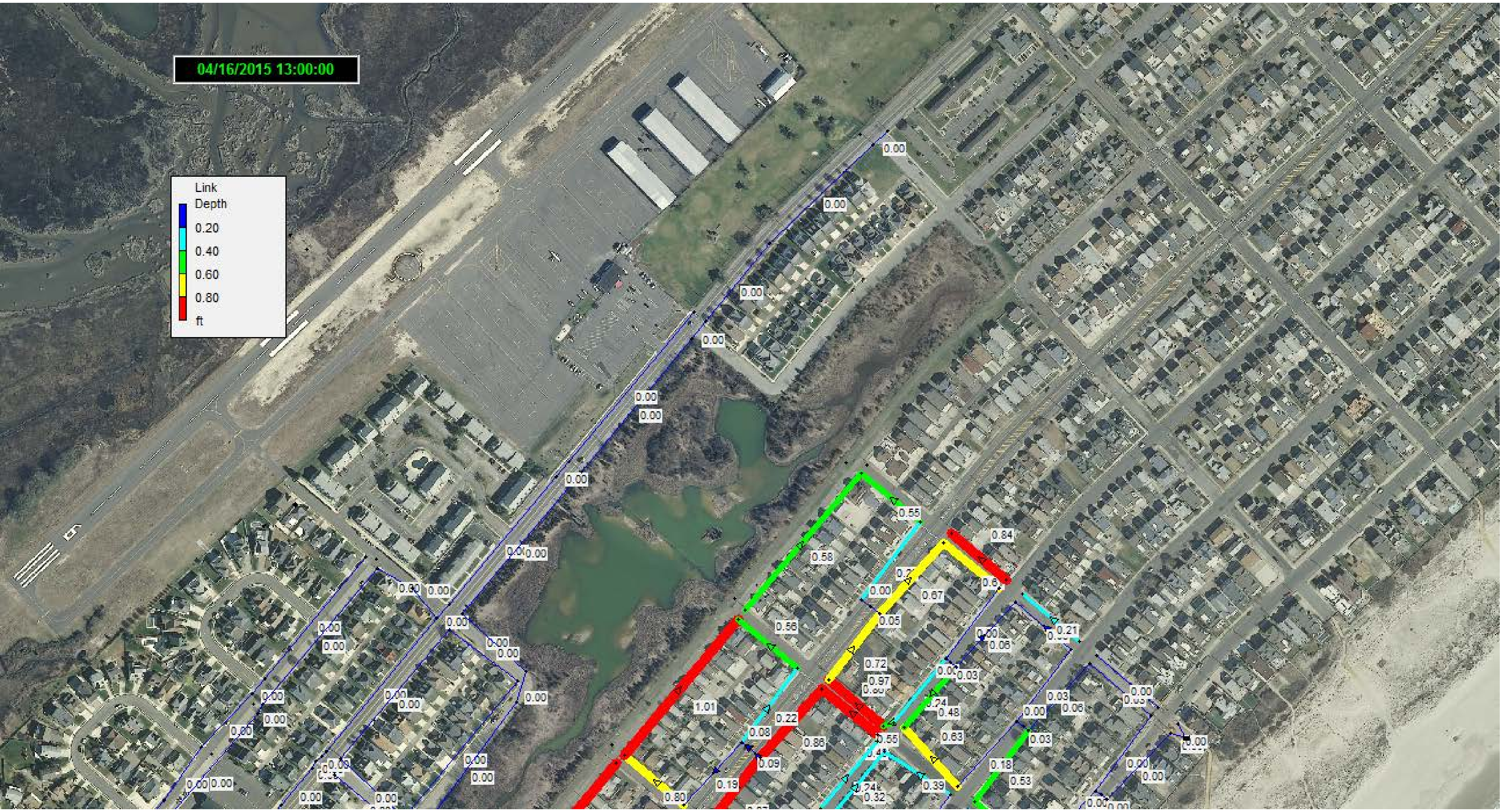
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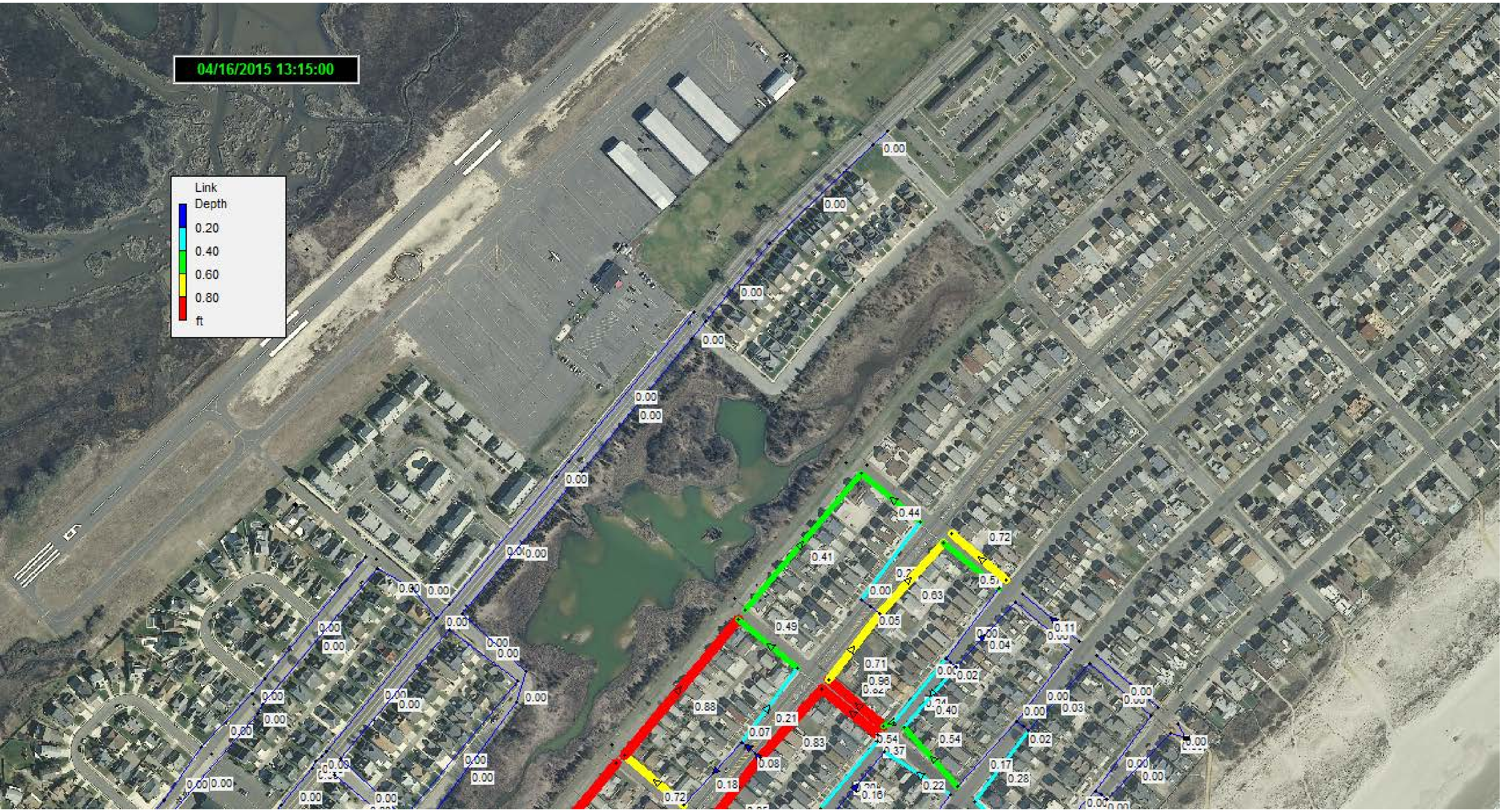
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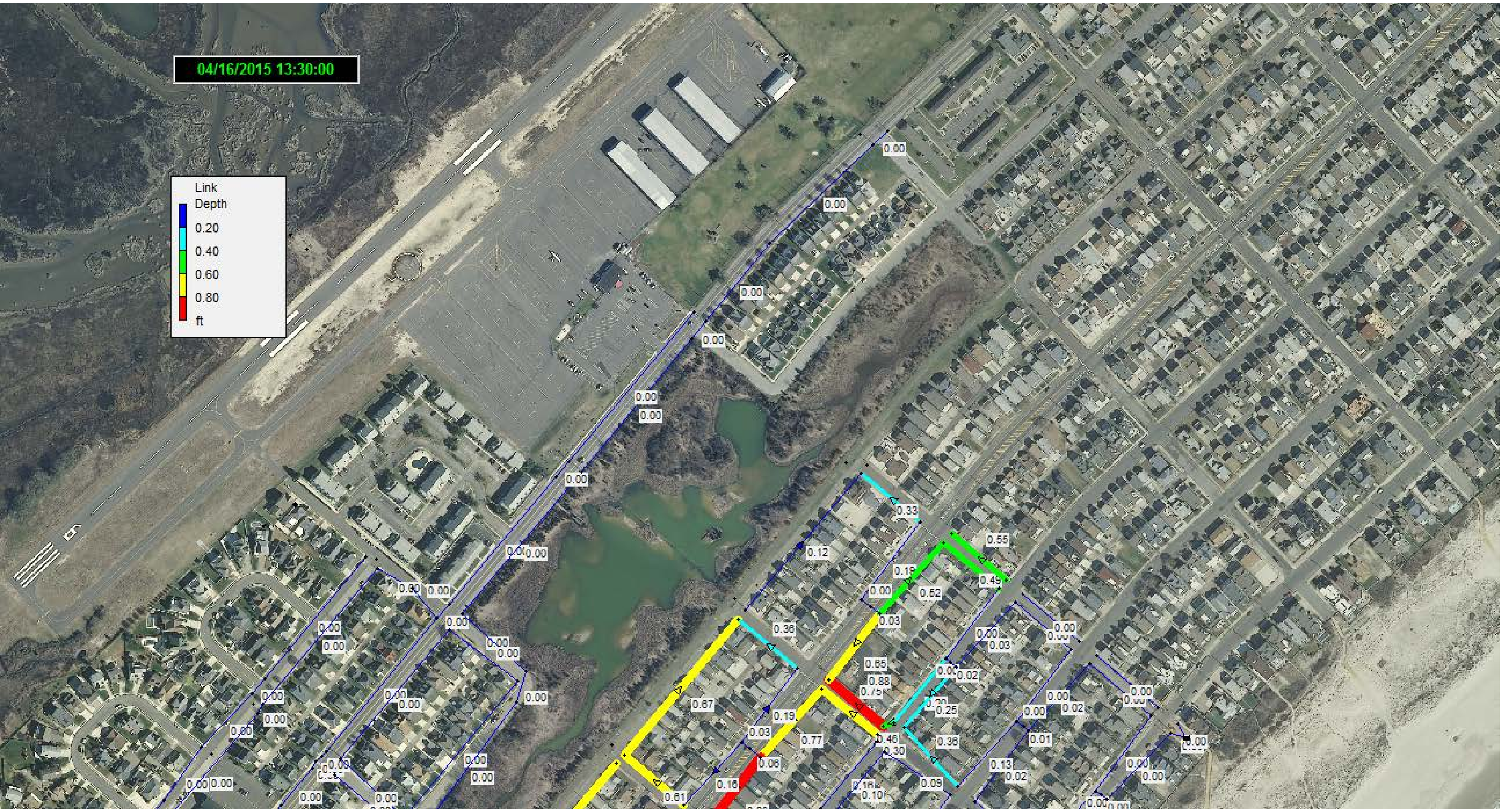

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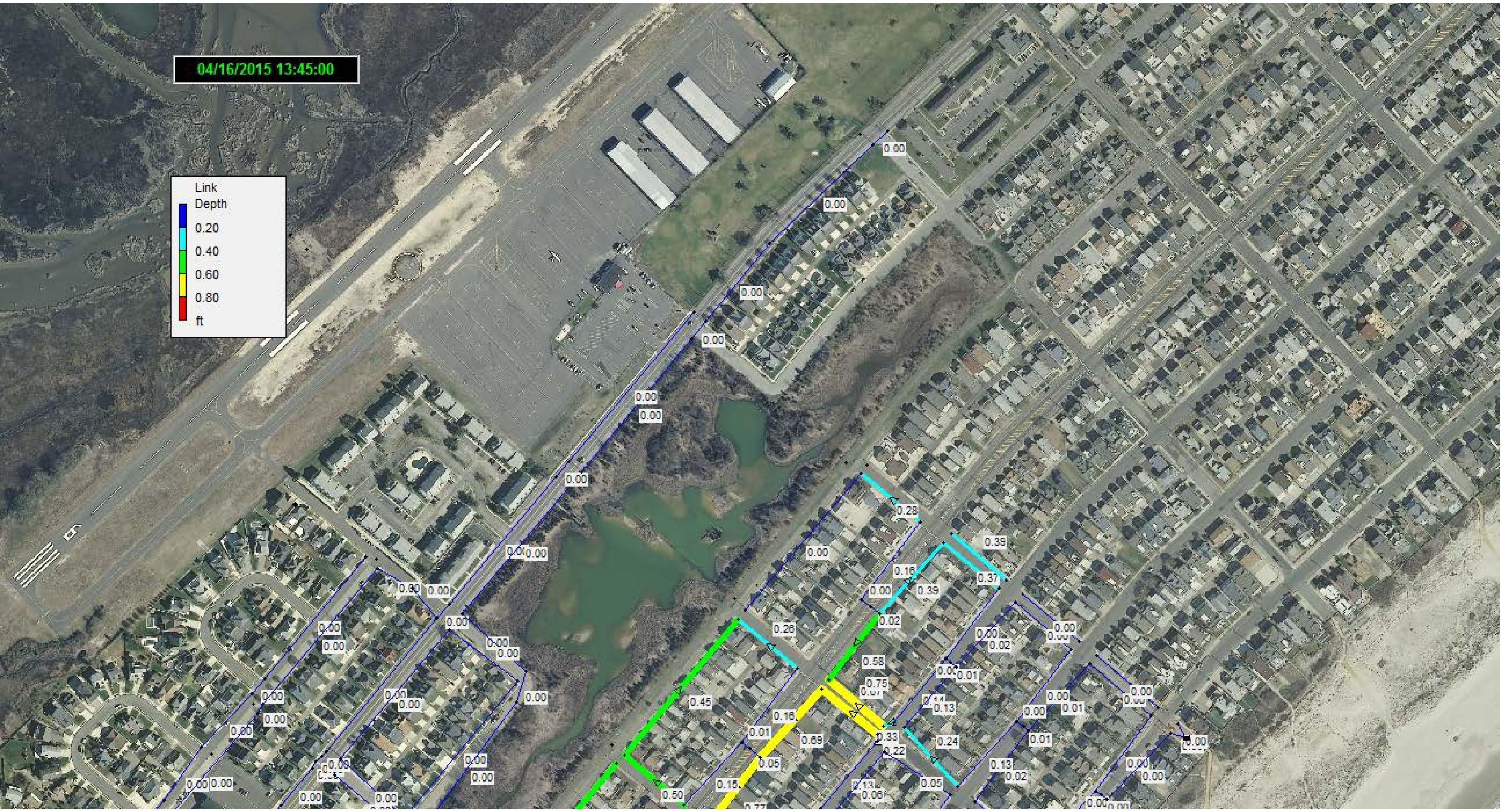
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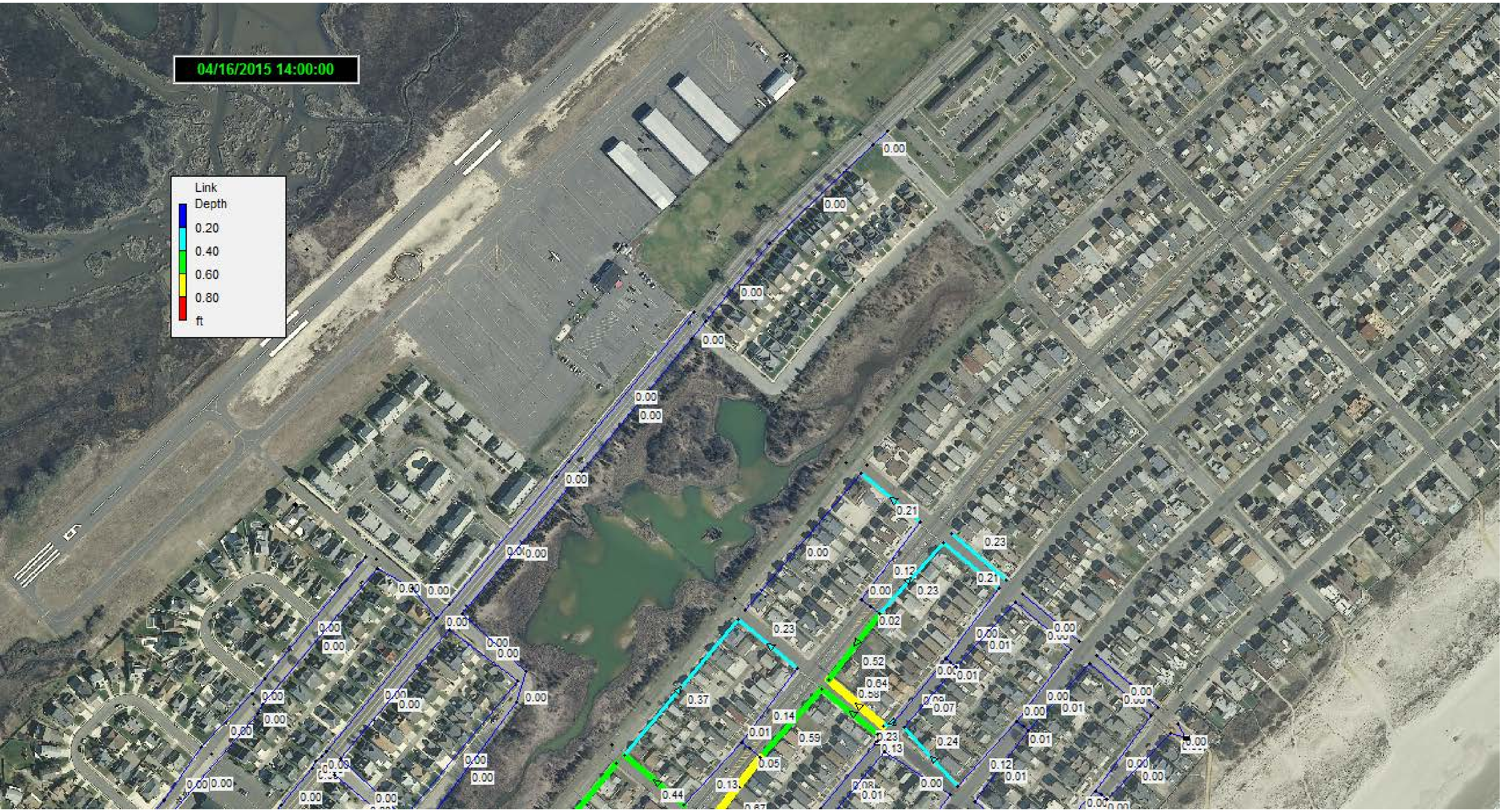
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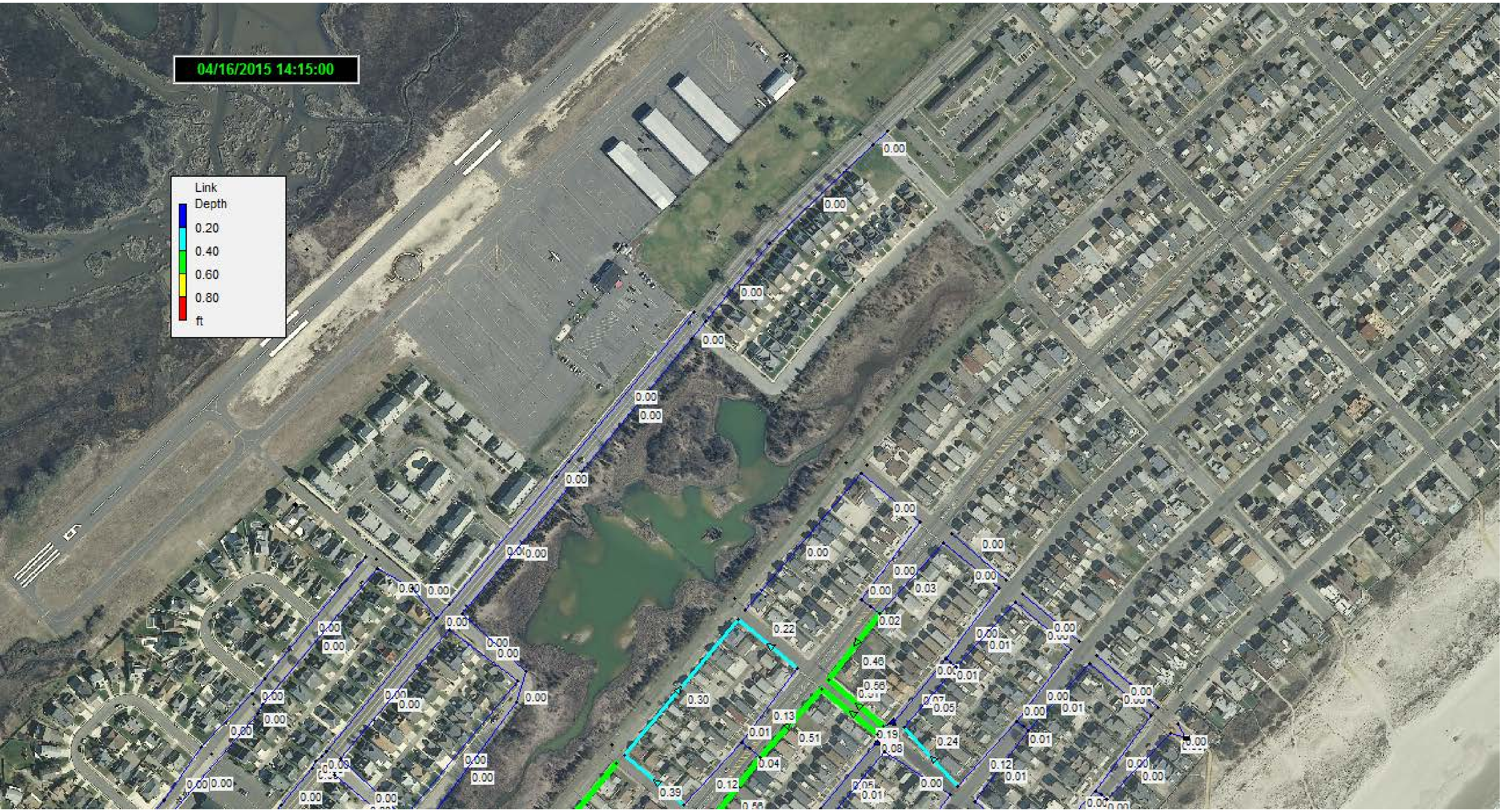

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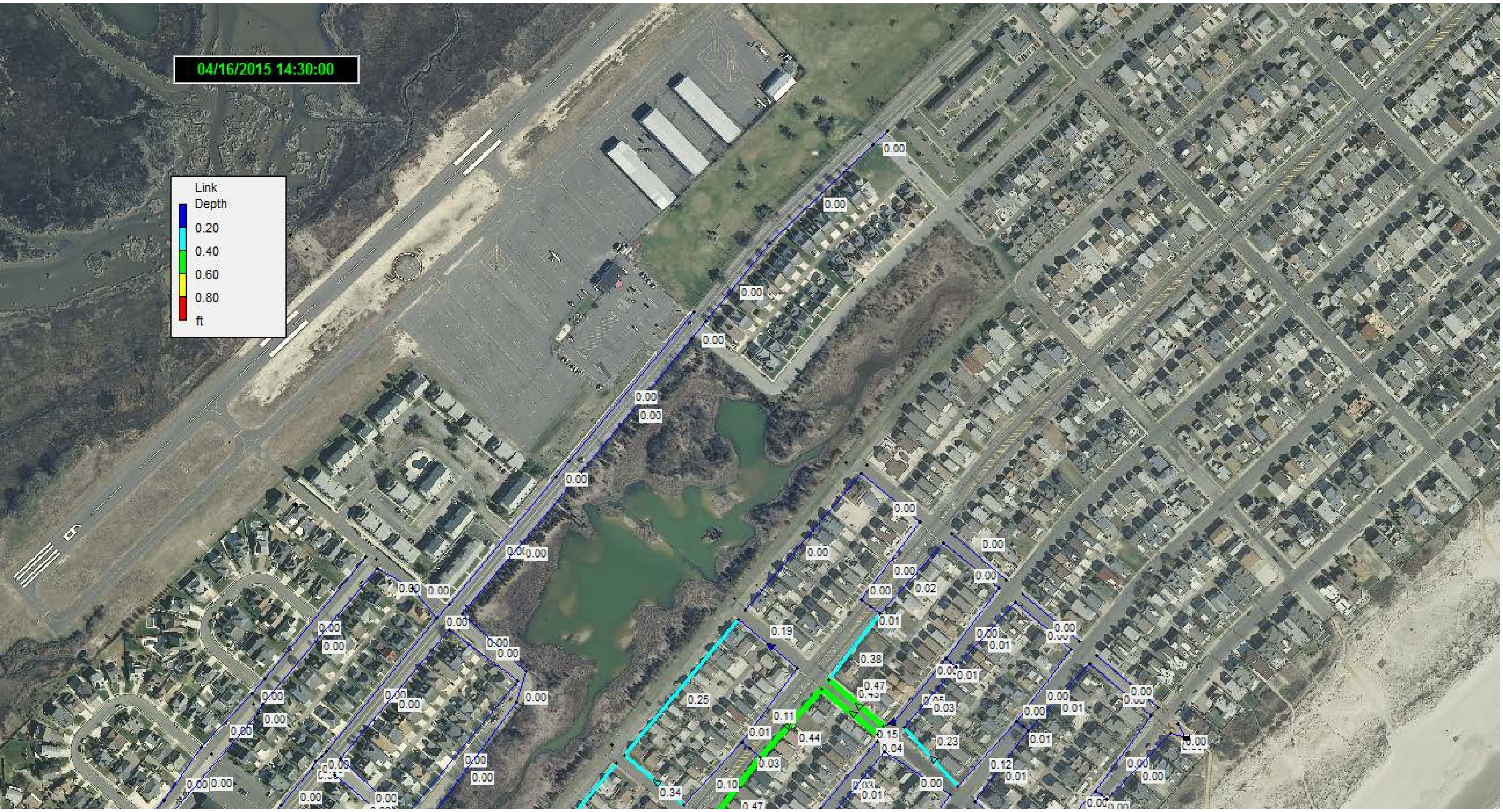
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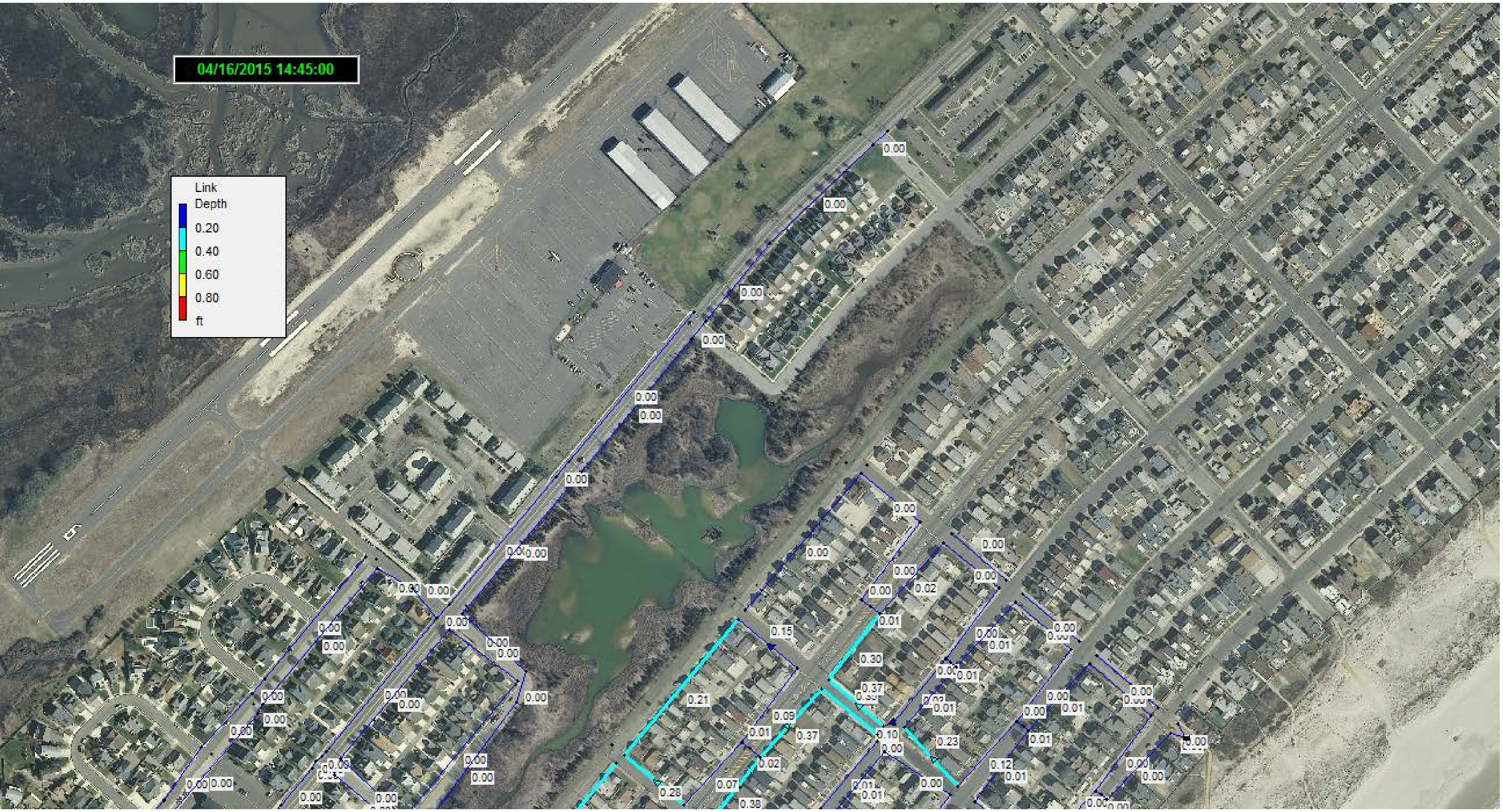
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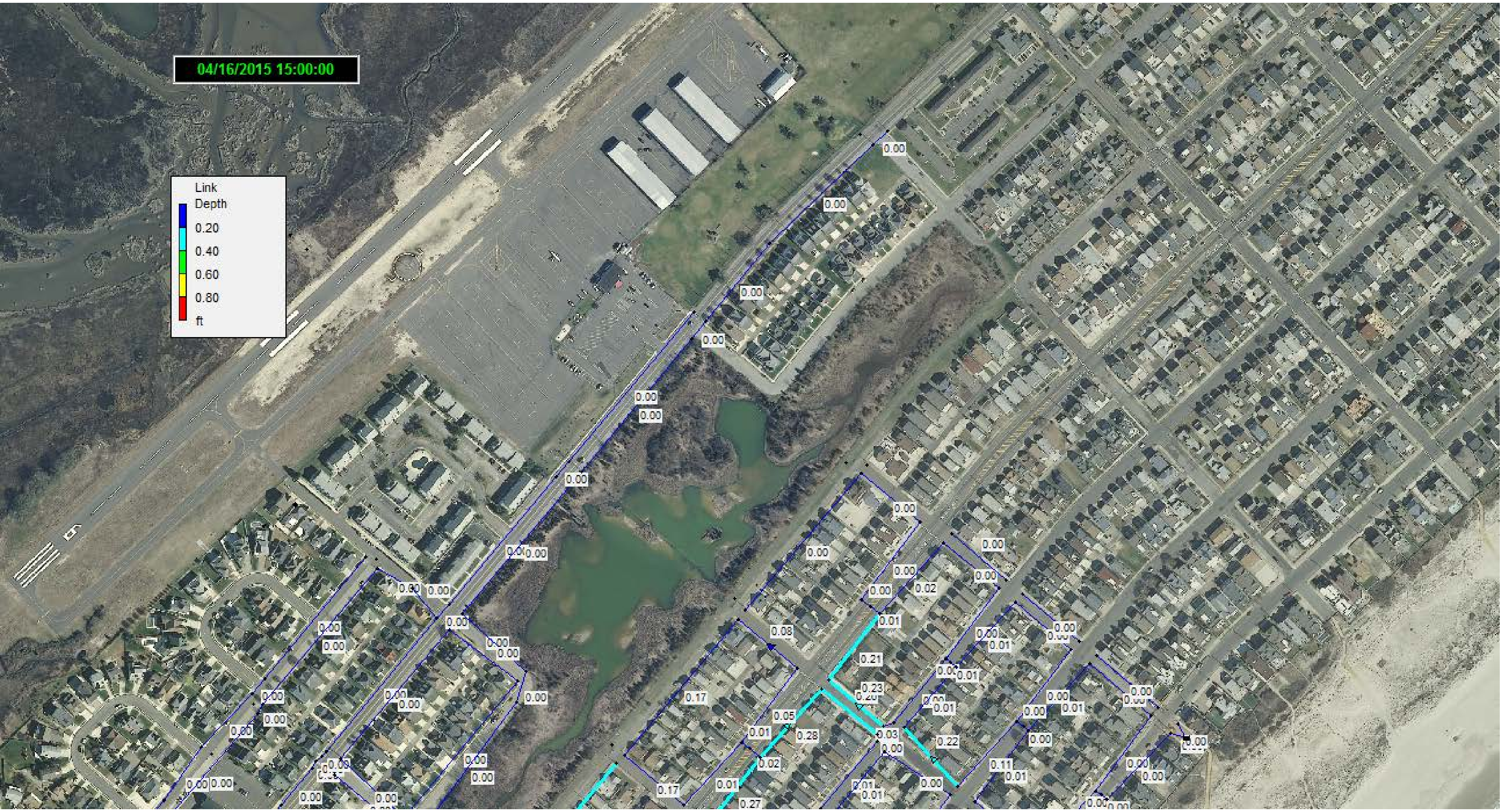
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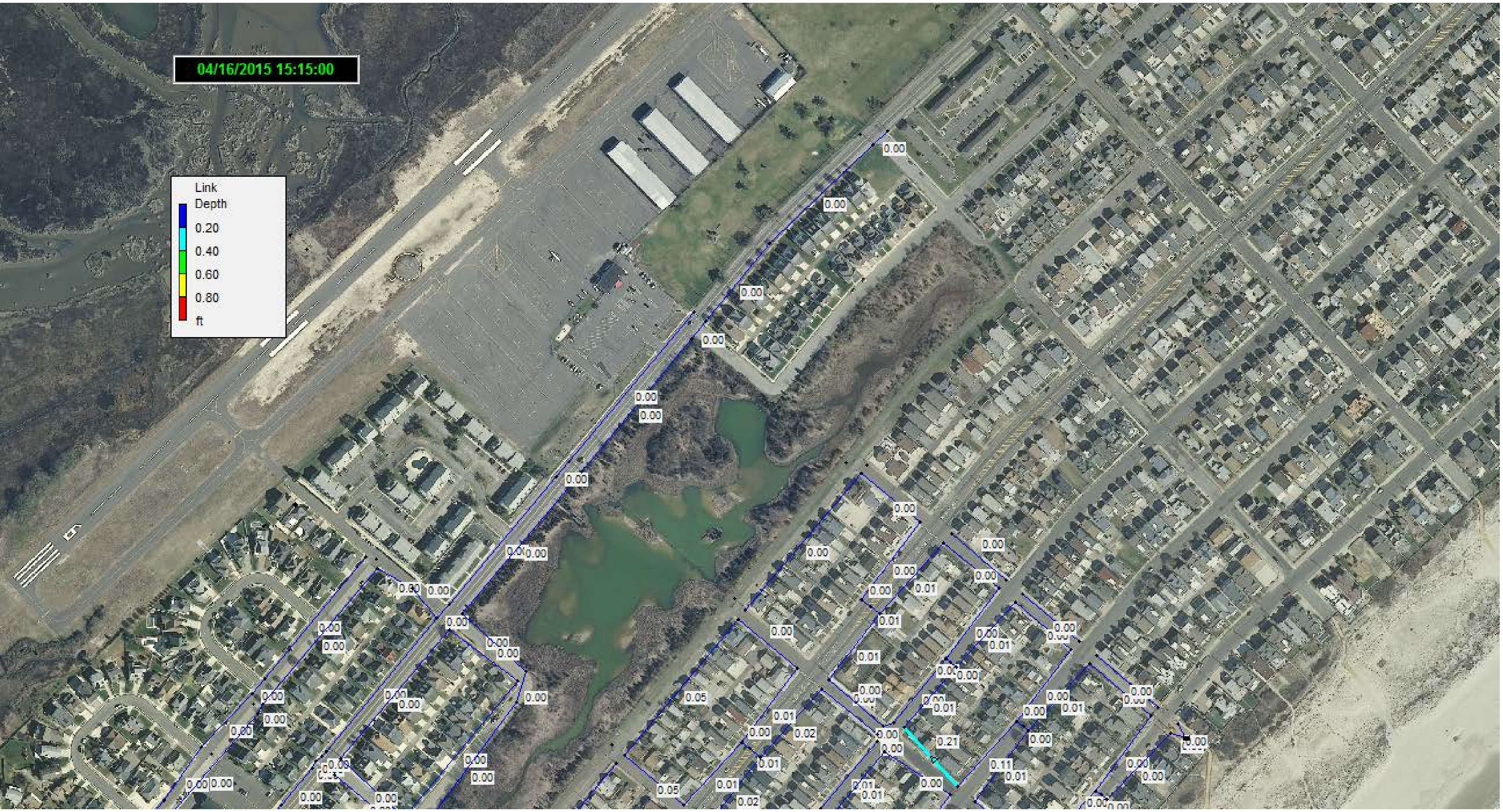

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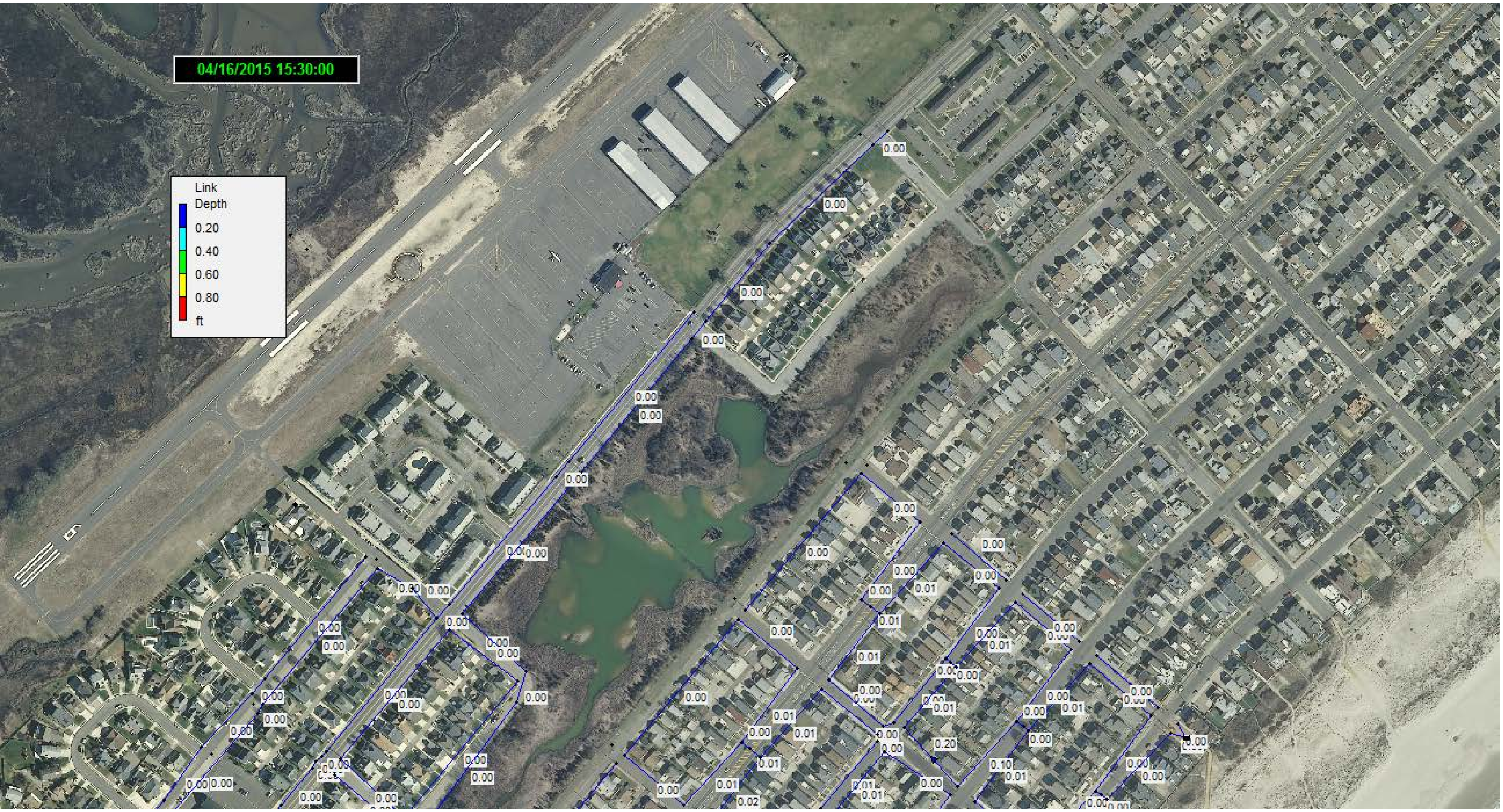
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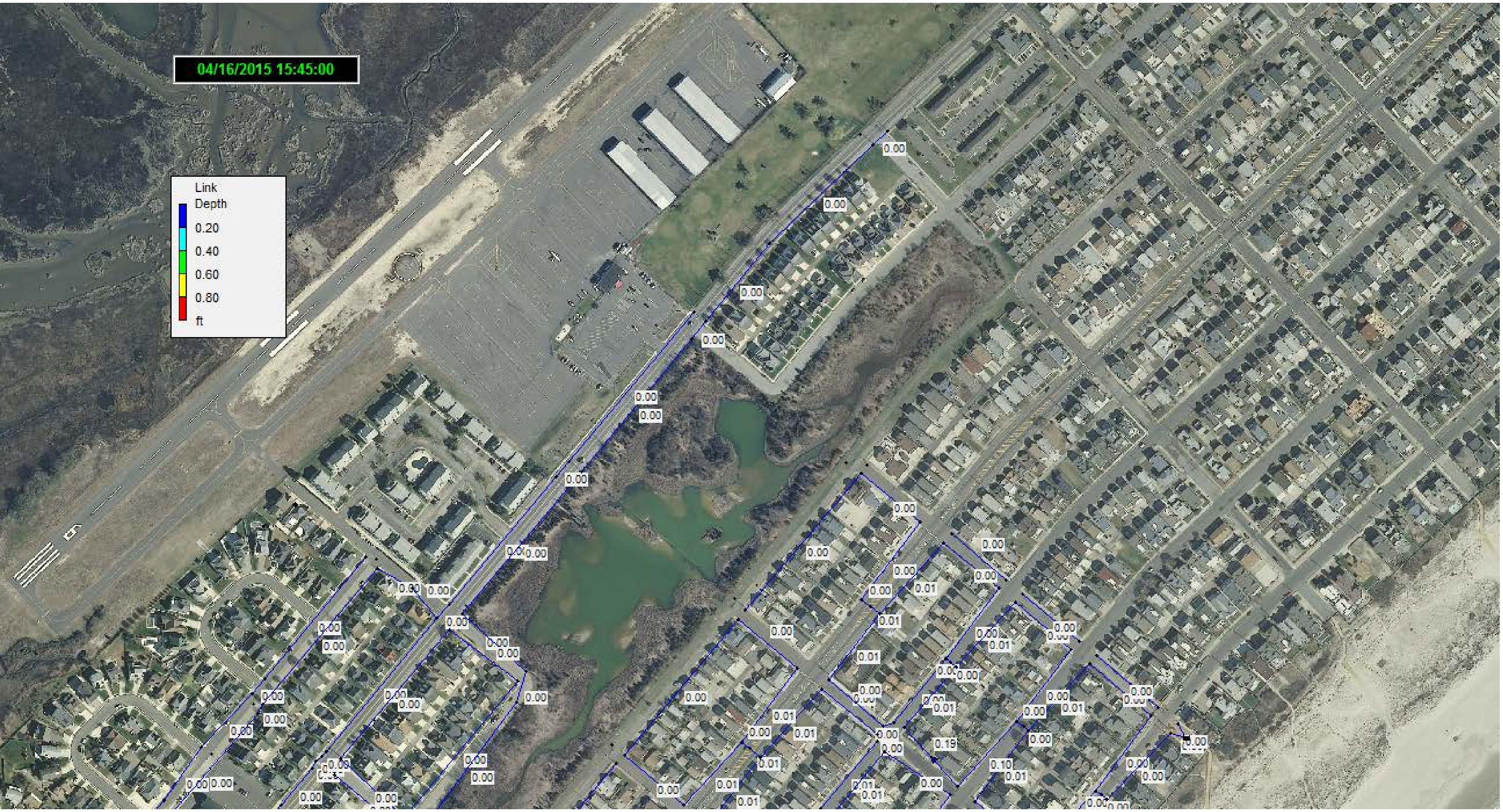
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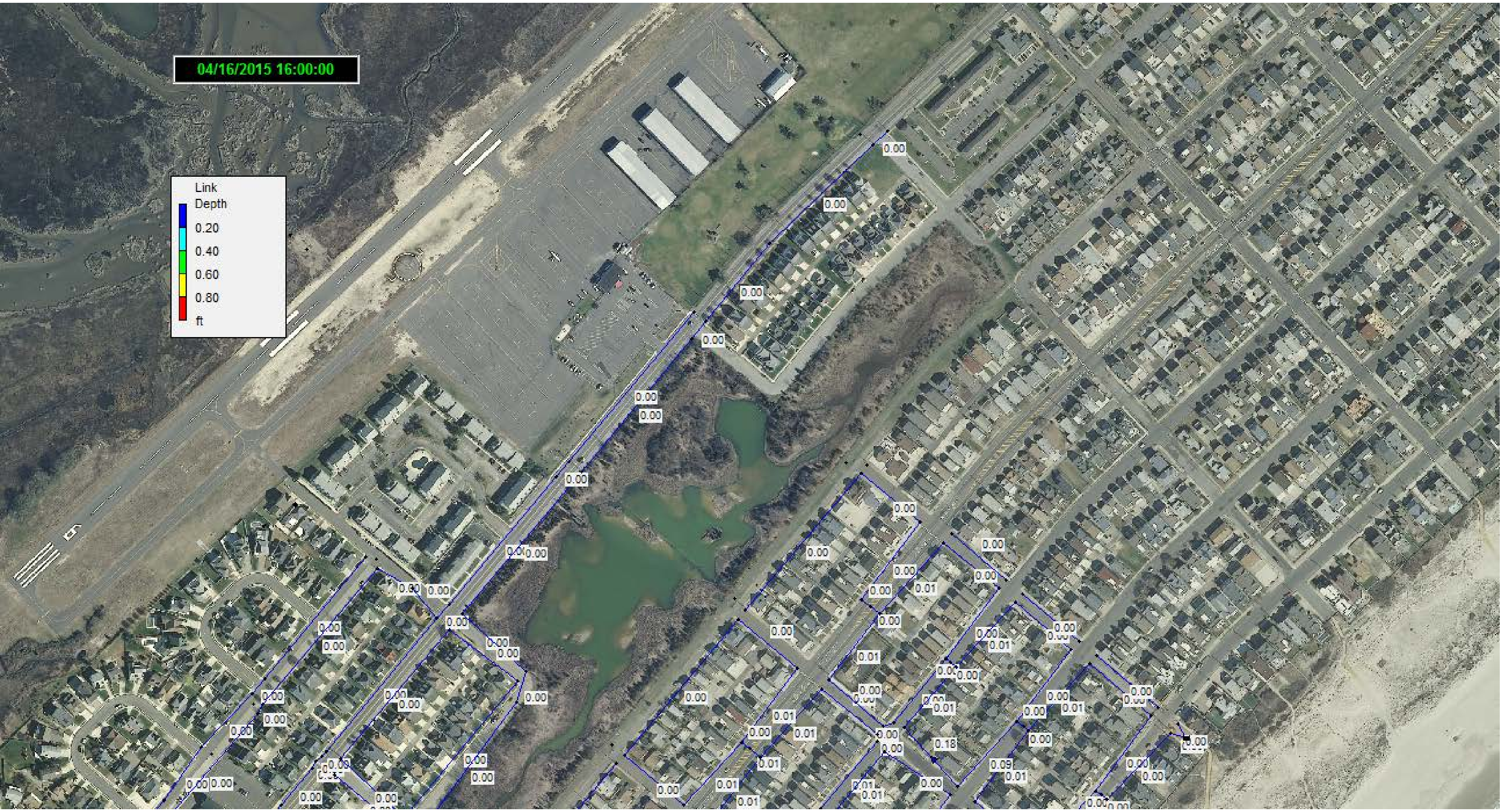
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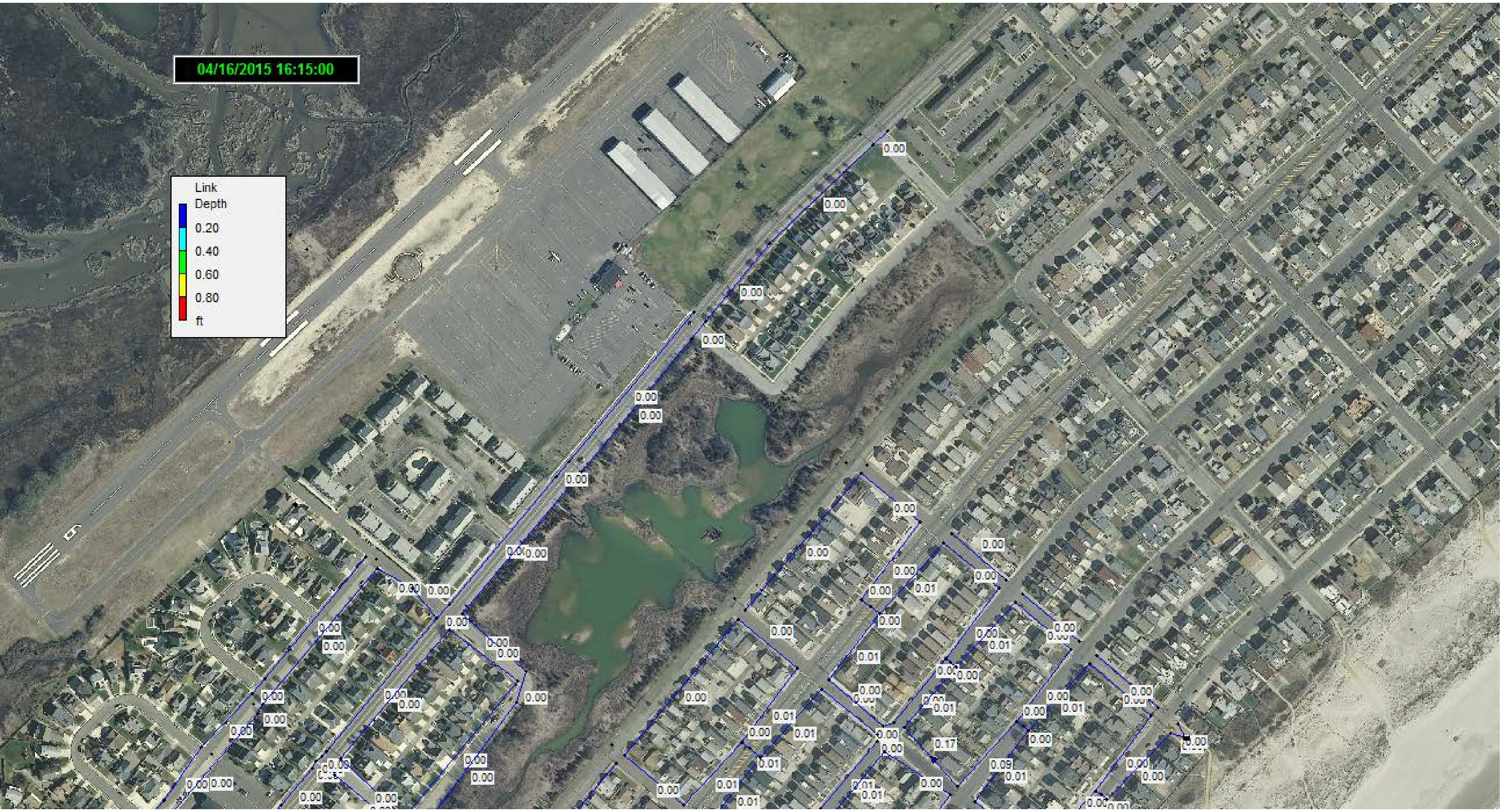
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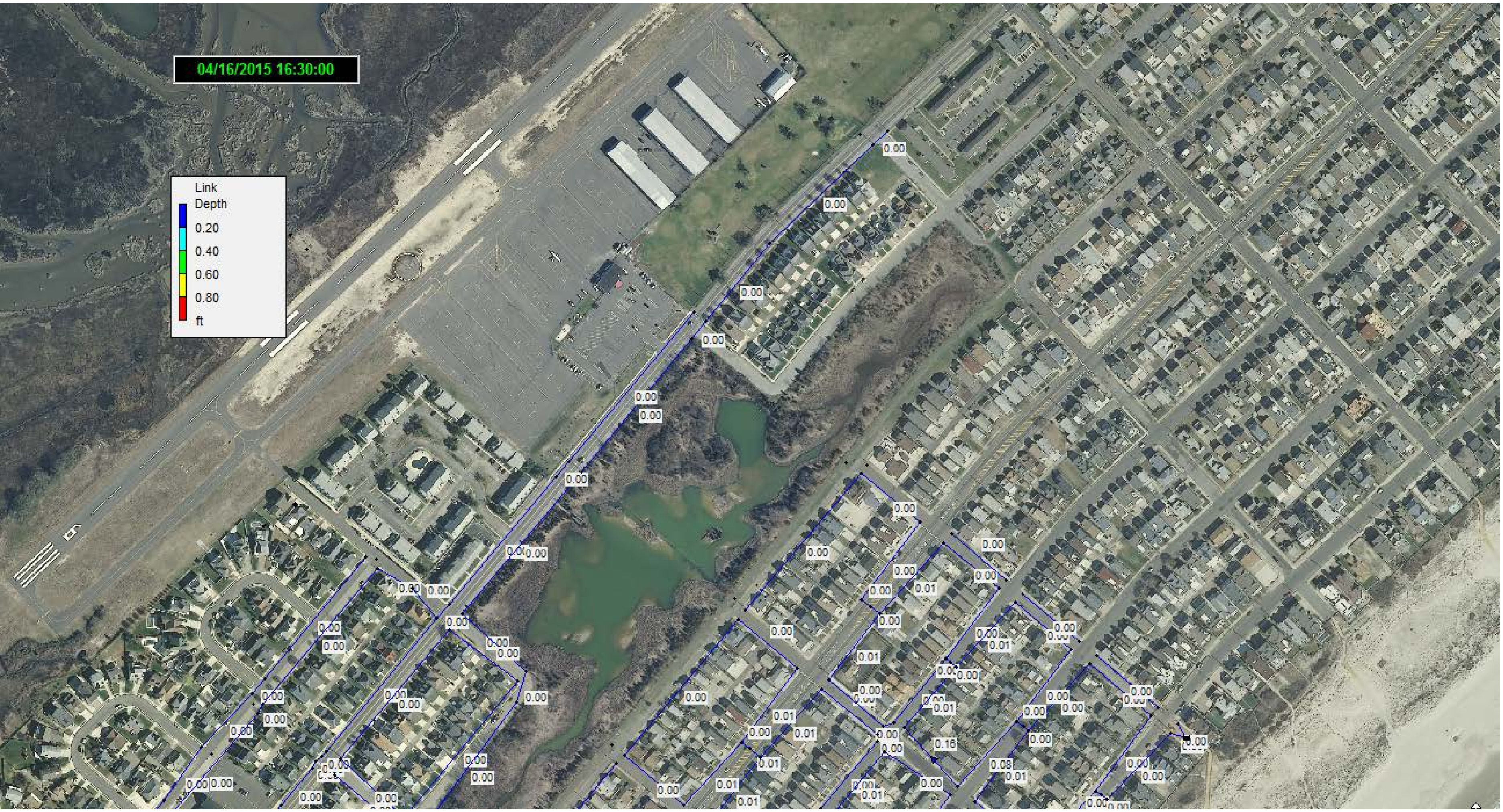
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