Final Report on the
Pilot Project for Advanced Floodplain Mapping

Submitted to the
Maine State Planning Office
Maine Floodplain Management Program

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Project Description

The object of this project was to evaluate the spatial differences between flood zones mapped using 2 foot interval contour data derived from LiDAR and the same areas mapped using the traditional MAPMOD approach. The goal was to quantify the differences between the two approaches, and help FEMA determine possible fiscal impacts of choosing one method over another. This would also help FEMA determine whether better results can be achieved by increasing map accuracy or by focusing more on engineering studies.

Current Federal Emergency Management Agency (FEMA) flood insurance rate maps (FIRM) were typically created from medium-resolution elevation data such as 1:100,000 or 1:24,000 scale data with 10 or 20-foot contour lines. During the MAPMOD[1] process, these data are aligned spatially with higher-resolution orthophotos, however that does not improve the spatial resolution of the delineated flood zones. The medium-resolution line showing the flood zone boundary is still a medium-resolution line.

New laser technology such as light detection and ranging (LiDAR) is available which can provide much higher resolution elevation data for delineation of flood zones. LiDAR data can typically provide 1, 2, or 4-foot contour lines for elevation, with a much higher precision suitable for mapping scales far better than 1:24,000. FEMA recently acquired LiDAR data for a coastal strip of Maine from roughly Kittery to Harpswell in York and Cumberland Counties. Complete LiDAR data also exists for the towns of Manchester and Augusta in Kennebec County.

Summary of Methodology

Nine FIRM panels were selected for GIS analysis on a somewhat random basis attempting to include a variety of zones in the "100 year" flood[2] category. The panels also had to be covered by the LiDAR generated 2 foot contour data. The object was to include flood zones in coastal, river and lake areas. Six panels were selected in Cumberland County, 2 in Brunswick, 2 in Falmouth and 2 in Freeport. Three panels were selected in Kennebec County, 2 in Augusta and 1 in Manchester.

For the six panels in Cumberland County, preliminary digital FIRM data existed. This had been completed in 2008 by MEGIS staff as part of an automation project for FEMA. Although the data were not finalized and accepted they were adequate for this exercise. In the area covered by each panel, the numbered A zones with static base flood elevation and A zones in floodways with base flood elevation lines were selected and placed in a new data layer. This layer was then modified so that the panel extents formed closure lines where needed. The number of attributes was reduced to the minimum needed. Where needed, the basic flood elevation lines were also selected and placed in a new data layer with attribution reduced to just elevation.

For the three panels in Kennebec County, it was necessary to automate the numbered A zones and A zones in a floodway along with the attendant basic flood elevation lines. This was done by rubber sheeting the scanned FIRM panels to fit the MEGIS 1 foot resolution orthoimagery and manually digitizing the lines.

Based on the elevations given as described above, contour lines were selected from the LiDAR 2 foot contour layer and placed in a new data layer. Where required, contour lines were interpolated between the 2 foot contour intervals. Smoothing lines were used to join contours. Where needed, the same panel edges as described above were used to form closed areas. In this way the "closure" lines for both the FIRM flood zones and the contour flood zones were exactly the same. The finished contour data layer was then made into a polygon layer for analysis.

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[1] In 2003 FEMA initiated the Map Modernization (MapMOD) program for an updated study of the location of flood zones and to create digital Flood Insurance Rate Maps incorporating local digital data.

[2] The 100-year flood is more accurately referred to as the 1% flood, since it is a flood that has a 1% chance of being equaled or exceeded in any single year. A 100-year flood has approximately a 63.4% chance of occurring in any 100-year period, not a 100 percent chance of occurring.

Flooded Area Comparisons
The FIRM flood zones and the contour generated flood zones were compared as a union of polygons in ArcGIS. The area in acres was calculated for two sections. First, places flooded by the contour zones but not by the FIRM zones. Second, places not flooded by the contour zones but flooded by the FIRM zones. The sum of both is the total FIRM error. These results are presented on page 12.

Structures
In order to determine whether or not any structure changed zone status, both the FIRM flood zones and the contour flood zones were examined in outline over high resolution orthoimagery. In Cumberland County ½ foot resolution orthoimagery[3] was used and in the Augusta-Manchester area 1 foot resolution orthoimagery[4] was used. The analysis was done at scales between 1:500 and 1:2000 on screen. A structure was designated as being in a zone if it was *in any way touched* by the zone lines. A point was placed over each structure found to be in either the FIRM flood zone, the contour flood zone or both and the point was coded accordingly. Docks, wharves, boat houses, dams and like facilities were not included. Only those things which were clearly substantial structures were counted. This data is presented on page 13.

Impervious areas and Land Use Land Cover
The available data sets were imagery[5]. A section of each covering the study area was converted to a polygon data set. This allowed for overlay analysis and geometry calculation. The overlaps between the FIRM flood zones, the contour flood zones and the two land cover data sets were determined in ArcGIS with clip analysis. This data is presented on page 1 and pages 16 to 24.

Developable Land
This was a subset of the results of the land use land cover analysis. Included were areas in land type that might be reasonably considered "developable" – forest, pasture, etc. Excluded were already developed land and also land certainly or probably not developable – open water, unconsolidated shore, wetlands, etc. This data is presented on page 15.

Public Lands
The available data set was federal, state and non-profit ownership[6]. The overlaps between the FIRM flood zones, the contour flood zones and the ownership data set were determined in ArcGIS with clip analysis. This data is presented on pages 25 and 26.

Summary of Results

The differences between the FIRM flood zones and the contour flood zones were significant. The largest difference between the FIRM zones and contour zones was 227.08 acres and the smallest was 34.4 acres. The average difference was 82.15 acres. Based on contour data, 54 structures would have gone into a flood zone and 117 would have come out. A total of 171 would have changed zone status.

Differences between FIRM zone lines and contour lines are illustrated by graphics beginning on page 6. Figure 1 shows an unexpected road flooding based on the static flood elevation given in the FIRM panel. An estimate of the extent of the 197 foot flood zone was provided by the U S Geological Survey Maine Water Science Center in Augusta, Me.

[3] Geolibrary data set ortho_hf, o.5 foot ground sample distance, natural color, flown leaf off in the spring of 2001
[4] Geolibrary data set ortho_1f, 1 foot ground sample distance, natural color, flown leaf off in the spring of 2004
[5] MEGIS data sets imperv and melcd. http://megis.maine.gov/catalog/catalog.asp?state=2&extent=cover
[6] MEGIS data set mecnslnd. http://megis.maine.gov/catalog/catalog.asp?state=2&extent=cover

As seen in Figure 2, some of the lines between FIRM flood zones and contour flood zones were from 350 to 570 meters apart. Figure 3 shows how even small changes in flood zone delineations can change the flood zone status of structures.

This project dealt only with FIRM flood zones having elevation information. Figure 4 shows an example of an A zone for which no base flood elevation data has been determined, or at least is not available. These “un-numbered A zones” pose the greatest difficulty for cartographers attempting to recompile existing FIRM maps to an accurate base.

Lastly, a brief look at economic consequences. On the three panels in Kennebec County, it was estimated that approximately 84 structures were incorrectly mapped. The estimated median house or condo value in Kennebec County in 2007 was $144,500[7]. Using that figure the value of the incorrectly mapped structures would be about $12.1 million. The corresponding numbers for the 6 panels in Cumberland County were 87 structures judged incorrect, a 2007 median value of $251,600 giving a total of about $21.9 million. These are admittedly broad generalizations but they show the monetary proportions of potentially incorrect mapping on just 9 panels.

Recommendations

First and most obvious is the recommendation that when attempting to recompile and /or digitize existing FIRM maps, the most accurate elevation data available should be referenced. In this project 2 foot interval contours derived from LIDAR data were used including interpolating to the nearest 1 foot contour. Fortunately LIDAR collection is no longer as rare and expensive as it has been in the past and we can look for future collection in Maine especially along the southern and central coastal townships. It is also know that some Maine communities have contour data available in the 2 foot to 5 foot interval range. It would be well to check with local governments before any recompilation of the FIRM.

Second, in the case of FIRM flood zones with no Base Flood Elevation (i.e. un-numbered A Zones) it is possible to get an estimate. There is software available that can provide an approximate Base Flood Elevation (BFE). HECRAS[8] is used for riverine areas and Quick 2[9] is a simplified version developed for FEMA to address approximate A zones. An estimate should be better than no BFE at all in recompilation and digitizing.

Third it is suggested that given the inadequacies of the paper FIRM any recompilation should at least look at and existing elevation data. All of Maine is covered by digital contours with intervals of 10 feet, 20 feet or 3 meters. It is highly probable that some FIRM flood zones could be improved simply by interpolating between existing contour lines.

[7] http://www.city-data.com/county
[8] http://en.wikipedia.org/wiki/HEC-RAS
[9] http://www.fema.gov/plan/prevent/fhm/dl_qck22.shtm

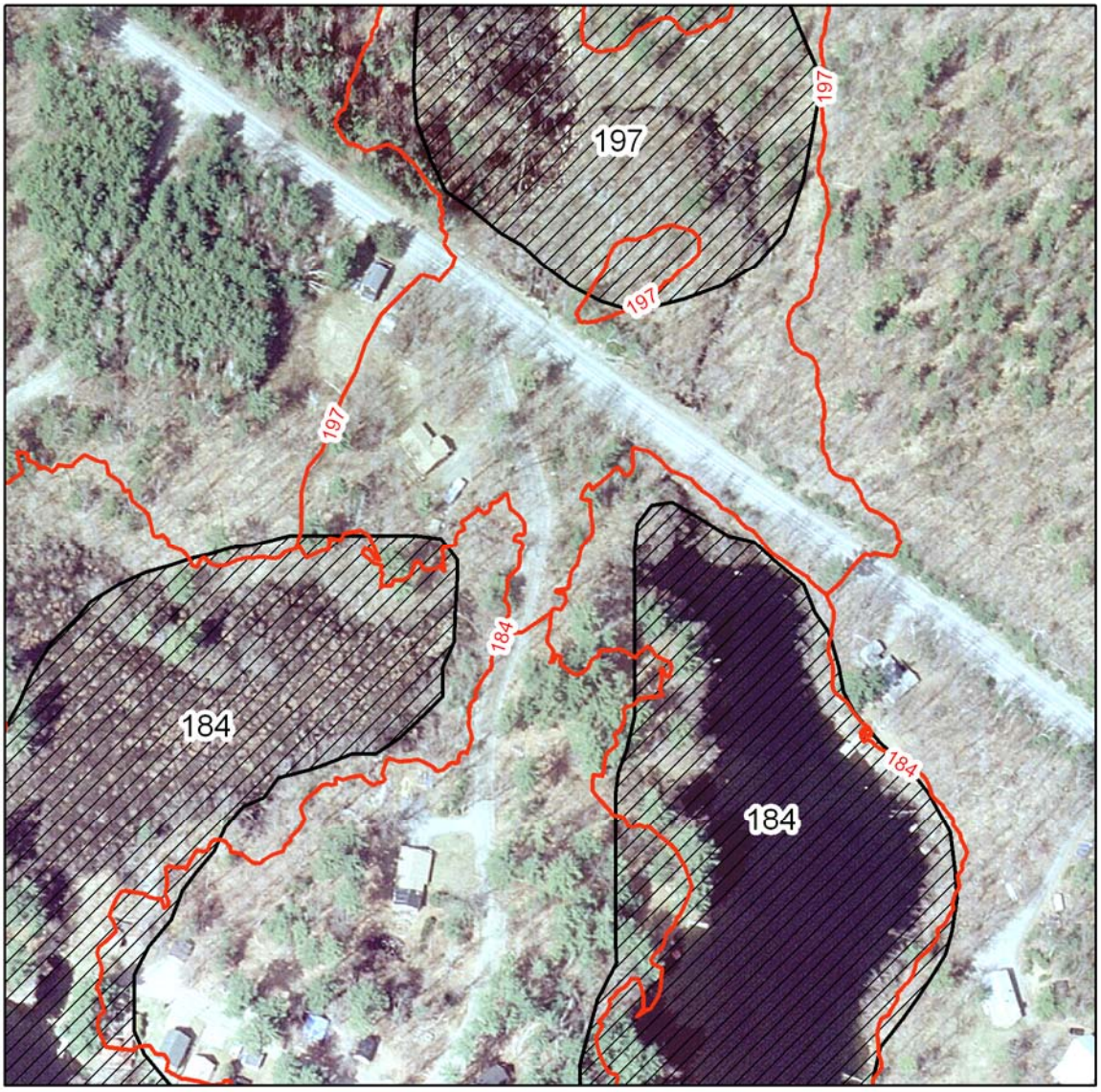

Figure 1

Figure 1 shows an area of Panel 230067 0008C in Augusta at the north end of Togus Pond at a scale of 1 inch = 200 feet. The cross-shaded areas represent the extent of the FIRM AE zones with a static base flood elevation of 197 feet in the upper zone and 184 feet in the lower zone. The red lines represent the 184 foot and 197 foot (interpolated) from the 2 foot contours derived from LiDAR. The aerial image is 1 foot resolution orthoimagery flown in 2004. Note that the 197 foot elevation would flood over the road and into the lower zone.

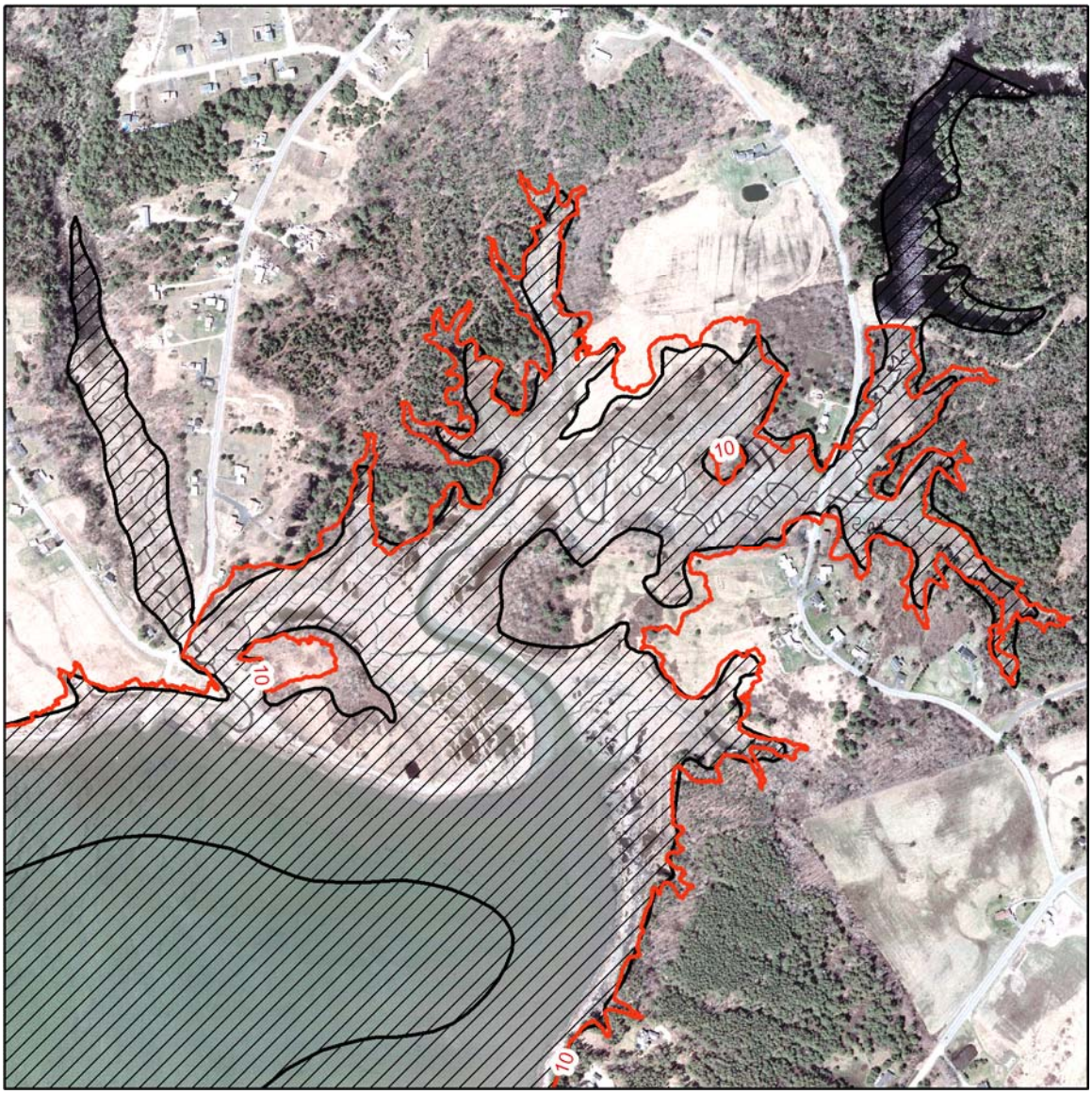

Figure 2

Figure 2 shows an area of Panel 230042 0026B in Brunswick on Maquoit Bay at a scale of 1 inch = 800 feet. The cross-shaded areas represent the extent of the FIRM A2 zones with a static base flood elevation of 10 feet. The red lines represent the 10 foot contour from the 2 foot contours derived from LiDAR. The aerial image is 0.5 foot resolution orthoimagery flown in 2001. This is to illustrate the often considerable differences between the two methods. Note the area in the center flooded as per the new contours but not on the FIRM and the reverse situation to the left center and upper right.

Figure 3

Figure 3 shows an area of Panel 230239 0011B in Manchester on Lake Cobbosseecontee at a scale of 1 inch = 200 feet. The cross-hatched areas represent the extent of the FIRM A3 zone with a static base flood elevation of 170 feet. The red lines represent the 170 foot contour from the 2 foot contours derived from LiDAR. The aerial image is 1 foot resolution orthoimagery flown in 2004. This is a good illustration of structures being in or out of a flood zone depending on which method is used.

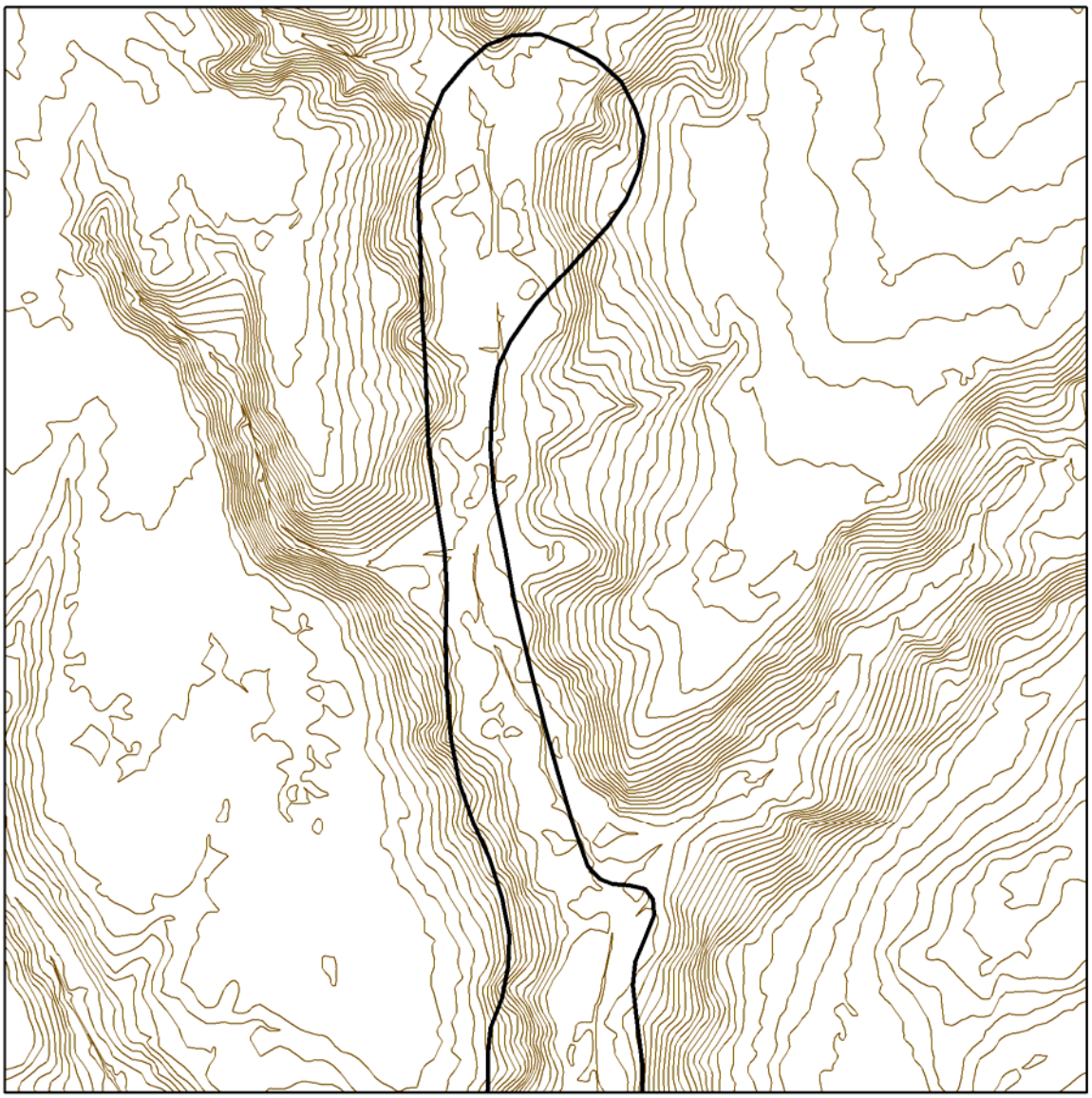

Figure 4

Figure 4 shows part of Panel 230046 0013B in Freeport. The heavy black line is the preliminary digital version of an un-numbered A zone. The lighter lines are 2 foot contours derived from LiDAR. The base flood elevation of this A zone is not available but it is obvious it does not fit the terrain. The next figure shows the same A zone with orthoimagery in the background.

Figure 5

Figure 5 shows the same part of Panel 230046 0013B as shown in figure 4. The unnumbered A zone is again shown in a heavy black line. The orthoimagery in the background is 0.5 foot resolution orthoimagery flown in 2001. Even with high resolution orthoimagery, the delineation of this zone is difficult without accurate elevation data.

Appendix I

Community	Panel Number
Augusta	2300670008C
Augusta	2300670012C
Brunswick	2300420015B
Brunswick	2300420026B
Falmouth	2300450008B
Falmouth	2300450009B
Freeport	2300460013B
Freeport	2300460014B
Manchester	2302390011B

Appendix II

Land Area
(in acres)

Panel Community	Area not in FIRM flood zones but in LIDAR flood zones	Area in FIRM flood zones but not in LIDAR flood zones	Total FIRM difference
230045008B Falmouth	29.19	4.84	34.03
2300670008C Augusta	26.15	71.97	98.12
2300450009B Falmouth	34.48	11.26	45.74
2302390011B Manchester	20.32	22.08	42.40
2300670012C Augusta	55.45	9.58	65.03
2300460013B Freeport	30.21	24.00	54.22
2300460014B Freeport	28.18	16.08	44.26
2300420015B Brunswick	99.79	177.30	277.08
2300420026B Brunswick	38.70	39.74	78.44
Totals	362.47	376.85	739.32

Structures

Panel Community	Number Removed[10] Based on new contours	Number Added[11] Based on new contours
2300450008B Falmouth	0	0
2300670008C Augusta	34	13
2300450009B Falmouth	4	1
2300450011B Manchester	14	6
2300670012C Augusta	7	10
2300460013B Freeport	4	9
2300450014B Freeport	12	14
2300420015B Brunswick	42	1
2300420026B Brunswick	0	0
Totals	117	54

[10] The number of structures which, based on the 2 foot contour data, **should not be in** a flood zone but according to the FIRM **are** in a flood zone.

[11] The number of structures which, based on the 2 foot contour data, **should** be in a flood zone but according to the FIRM **are not** in a flood zone.

Impervious Surfaces
(in acres)

Panel Community	Area not in FIRM flood zones but in LIDAR flood zones	Area in FIRM flood zones but not in LIDAR flood zones	Total FIRM difference
2300450008B Falmouth	.17	.22	.39
2300670008C Augusta	1.21	.44	1.65
2300450009B Falmouth	.56	.59	1.15
2302390011B Manchester	.47	1.45	1.92
2300670012C Augusta	.69	.14	.83
2300460013B Freeport	1.65	.44	2.09
2300460014B Freeport	1.33	.17	1.50
2300420015B Brunswick	2.27	10.89	13.16 *
2300420026B Brunswick	0	0	0
Totals	8.35	14.34	22.69

* The FIRM showed a fairly large area of parking lots and roadways being flooded. The corresponding LiDAR contours showed a much smaller area being flooded.

Developable Land
(in acres)

Panel Community	Area not in FIRM flood zones but in LIDAR flood zones	Area in FIRM flood zones but not in LIDAR flood zones	Total FIRM difference
2300450008B Falmouth	10.10	1.90	12.00
2300670008C Augusta	15.43	56.21	71.64
2300450009B Falmouth	6.49	3.50	9.99
2302390011B Manchester	18.27	18.00	36.27
2300670012C Augusta	23.73	5.33	29.06
2300460013B Freeport	20.50	16.25	36.75
2300460014B Freeport	4.84	4.76	9.60
2300420015B Brunswick	41.47	83.06	124.53
2300420026B Brunswick	15.31	9.75	25.06
Totals	156.16	198.76	354.92

Land Use/Land Cover
(in acres)

Panel 230045008B Falmouth	Area not in FIRM flood zones but in LIDAR flood zones	Area in FIRM flood zones but not in LIDAR flood zone	Total FIRM difference
Deciduous Forest	1.63	.12	1.75
Developed Low Intensity	.79	.39	1.18
Developed Medium Intensity	.04	.09	.13
Developed Open Space	2.09	1.35	3.44
Evergreen Forest	3.35	.59	3.94
Mixed Forest	3.50	.37	3.87
Open Water	10.62	.81	11.43
Pasture/Hay	1.60	.04	1.64
Unconsolidated Shore	1.87	.17	2.04
Wetlands	3.58	.76	4.34
Totals	29.07	4.69	33.76

Land Use/Land Cover
(in acres)

Panel 230067008C Augusta	Area not in FIRM flood zones but in LIDAR flood zones	Area in FIRM flood zones but not in LIDAR flood zones	Total FIRM error
Cultivated Land	0	.29	.29
Deciduous Forest	3.70	14.12	17.82
Developed Low Intensity	.32	.86	1.18
Developed Open Space	.12	.12	.24
Evergreen Forest	.46	11.90	12.36
Forest Regeneration	.74	.37	1.11
Forested Wetland	4.76	10.86	15.62
Grassland/Herbaceous	.04	0	.04
Heavy Partial Cut	.93	1.35	2.28
Light Partial Cut	2.98	11.70	14.68
Mixed Forest	6.54	16.45	22.99
Open Water	3.40	2.09	5.49
Road/Runway	1.45	.12	1.57
Wetlands	.49	1.58	2.07
Totals	25.93	71.79	97.72

Land Use/Land Cover
(in acres)

Panel 230045009B Falmouth	Area not in FIRM flood zones but in LIDAR flood zones	Area in FIRM flood zones but not in LIDAR flood zones	Total FIRM difference
Deciduous Forest	0	.07	.07
Developed Low Intensity	1.50	.12	1.62
Developed Medium Intensity	.56	0	.56
Developed Open Space	10.00	2.22	12.22
Evergreen Forest	1.55	2.34	3.89
Mixed Forest	2.17	.66	2.83
Open Water	7.55	3.23	10.78
Pasture/Hay	2.76	.41	3.17
Road/Runway	0	.44	.44
Unconsolidated Shore	.17	.32	.49
Wetlands	8.05	1.25	9.30
Totals	34.33	11.06	45.39

Land Use/Land Cover
(in acres)

Panel 2302390011B Manchester	Area not in FIRM flood zones but in LIDAR flood zones	Area in FIRM flood zones but not in LIDAR flood zones	Total FIRM difference
Deciduous Forest	.12	.27	.39
Developed Low Intensity	0	.12	.12
Evergreen Forest	13.11	5.70	18.81
Heavy Partial Cut	0	.98	.98
Light Partial Cut	1.82	6.42	8.24
Mixed Forest	3.21	4.61	7.82
Open Water	1.16	1.87	3.03
Road/Runway	.44	1.63	2.07
Wetlands	.37	.34	.71
Totals	20.23	21.94	42.17

Land Use/Land Cover
(in acres)

Panel 230067012C Augusta	Area not in FIRM flood zones but in LIDAR flood zones	Area in FIRM flood zones but not in LIDAR flood zones	Total FIRM difference
Deciduous Forest	13.68	4.39	18.07
Developed Low Intensity	.09	.02	.11
Forest Regeneration	.39	0	.39
Forested Wetland	14.64	1.23	15.87
Heavy Partial Cut	.17	0	.17
Light Partial Cut	.96	0	.96
Mixed Forest	8.52	.93	9.45
Open Water	5.45	.54	5.99
Road/Runway	.88	.07	.95
Wetlands	10.49	2.24	12.73
Totals	55.27	9.42	64.69

Land Use/Land Cover
(in acres)

Panel 2300460013B Freeport	Area not in FIRM flood zones but in LIDAR flood zones	Area in FIRM flood zones but not in LIDAR flood zones	Total FIRM difference
Deciduous Forest	.02	.27	.29
Developed Low Intensity	1.25	.12	1.37
Developed Medium Intensity	.46	0	.46
Developed Open Space	.24	.17	.41
Evergreen Forest	5.23	10.91	16.14
Forested Wetland	0	.02	.02
Mixed Forest	14.72	4.86	19.58
Open Water	5.45	.54	5.99
Pasture/Hay	.44	.12	.56
Runway/Roadway	0	.09	.09
Scrub Shrub	.07	.07	.14
Unconsolidated Shore	3.87	3.80	7.67
Wetlands	1.70	2.84	4.54
Totals	33.44	23.81	57.25

Land Use/Land Cover
(in acres)

Panel 2300460014B Freeport	Area not in FIRM flood zones but in LIDAR flood zones	Area in FIRM flood zones but not in LIDAR flood zones	Total FIRM difference
Bare Land	.02	0	.02
Developed Open Space	2.22	.37	2.59
Evergreen Forest	1.28	2.22	3.50
Forested Wetland	.09	0	.09
Heavy Partial Cut	0	.02	.02
Mixed Forest	2.59	1.87	4.46
Open Water	14.35	4.12	18.47
Pasture/Hay	.93	.59	1.52
Scrub Shrub	0	.04	.04
Unconsolidated Shore	4.52	3.53	8.05
Wetlands	2.02	3.16	5.18
Totals	28.02	13.31	41.33

Land Use/Land Cover
(in acres)

Panel 2300420015B Brunswick	Area not in FIRM flood zones but in LIDAR flood zones	Area in FIRM flood zones but not in LIDAR flood zones	Total FIRM difference
Deciduous Forest	2.34	8.22	10.56
Developed High Intensity	.61	3.08	3.69
Developed Low Intensity	4.05	9.04	13.09
Developed Medium Intensity	2.42	6.49	8.91
Developed Open Space	5.65	16.07	21.72
Evergreen Forest	11.21	31.93	43.14
Forest Regeneration	0	.74	.74
Forested Wetland	3.53	8.69	12.22
Mixed Forest	24.82	35.17	59.99
Open Water	17.66	11.38	29.04
Pasture/Hay	2.54	6.66	9.20
Road/Runway	.32	1.11	1.43
Scrub Shrub	.54	.32	.86
Unconsolidated Shore	14.44	16.05	30.49
Wetlands	11.06	20.67	31.73
Totals	101.19	175.62	276.81

Land Use/Land Cover
(in acres)

Panel 2300420026B Brunswick	Area not in FIRM flood zones but in LIDAR flood zones	Area in FIRM flood zones but not in LIDAR flood zones	Total FIRM difference
Cultivated Land	.74	0	.74
Deciduous Forest	1.60	.91	2.51
Developed Open Space	.46	.37	.83
Evergreen Forest	4.54	5.11	9.65
Forested Wetland	3.55	5.80	9.35
Mixed Forest	6.24	3.33	9.57
Open Water	7.15	3.78	10.93
Pasture/Hay	2.17	.19	2.36
Road/Runway	.22	.51	.73
Scrub Shrub	0	.19	.19
Unconsolidated Shore	2.49	6.44	8.93
Wetlands	13.95	7.38	21.33
Totals	43.11	34.01	77.12

Public Lands
(area in acres)

Panel 2300450008B Falmouth	Area not in FIRM flood zones but in LIDAR flood zones	Area in FIRM flood zones but not in LIDAR flood zones	Total FIRM difference
MDOT (Maine Department of Transportation)	12.37	2.02	14.39

Panel 2300670008C Augusta	Area not in FIRM flood zones but in LIDAR flood zones	Area in FIRM flood zones but not in LIDAR flood zones	Total FIRM difference
No Public Lands			

Panel 2300450009B Falmouth	Area not in FIRM flood zones but in LIDAR flood zones	Area in FIRM flood zones but not in LIDAR flood zones	Total FIRM difference
MASO (Maine Audubon Society)	6.27	.88	7.15
MDOC (Maine Department of Conservation)	2.43	2.66	5.09

Panel 2302390011B Manchester	Area not in FIRM flood zones but in LIDAR flood zones	Area in FIRM flood zones but not in LIDAR flood zones	Total FIRM difference
No Public Lands			

Panel 2300670012C Augusta	Area not in FIRM flood zones but in LIDAR flood zones	Area in FIRM flood zones but not in LIDAR flood zones	Total FIRM difference
MDFW (Maine Department of Inland Fisheries and Wildlife)	5.21	2.37	7.58

Panel 2300460013B	Area not in FIRM flood zones	Area in FIRM flood zones

Freeport	but in LIDAR flood zones	but not in LIDAR flood zones	Total FIRM difference
No Public Lands			

Panel 2300460014B Freeport	Area not in FIRM flood zones but in LIDAR flood zones	Area in FIRM flood zones but not in LIDAR flood zones	Total FIRM difference
MDOC (Maine Department of Conservation)	2.02	2.79	4.81

Panel 2300420015B Brunswick	Area not in FIRM flood zones but in LIDAR flood zones	Area in FIRM flood zones but not in LIDAR flood zones	Total FIRM difference
MDOT (Maine Department of Transportation)	.81	1.16	1.97

Panel 2300420026B Brunswick	Area not in FIRM flood zones but in LIDAR flood zones	Area in FIRM flood zones but not in LIDAR flood zones	Total FIRM difference
No Public Lands			
Totals	29.11	11.88	40.99

Maps

These maps show the digitized FIRM flood zones compared with the flood zones derived from LiDAR with high resolution orthoimagery in the background. The maps are full size (24” x 36”) and at scales ranging from 1:5000 to 1:16000. They are listed by FIRM panel number and are in PDF format.

http://www.maine.gov/spo/maps/2300450008B_map.pdf

http://www.maine.gov/spo/maps/2300670008C_map.pdf

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http://www.maine.gov/spo/maps/2300420026B_map.pdf