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MEMORANDUM

To:	Robert Law, de maximis, inc.	**Date:**	May 17, 2013
From:	John Connolly, Peter Israelsson, Alyssa Thorvaldsen, and George Dang, Anchor QEA, LLC		
cc:	Rooni Mathew and Rafael Canizares, Moffatt & Nichol Marcia Greenblatt, Integral Consulting	**Project:**	120980-02.01
Re:	Lower Passaic River Surface Sediment Concentration Mapping		

INTRODUCTION

A method was developed by the CPG Modeling Team to generate continuous concentration maps for surface sediment (0 to 6 inches) contaminant concentrations in the Lower Passaic River Study Area (LPRSA). These maps are needed to set model initial conditions, assess time trends in surface-weighted average concentrations (SWACs), and support the delineation of target areas for sediment removal throughout the LPRSA. The application of this approach to 2,3,7,8-TCDD is presented here, focusing on 1995 and 2010 conditions between approximately River Miles (RMs) 1 to 7, the reach of the river with data available for both time periods[1]. The approach described herein continues to be refined as Contaminant Fate and Transport (CFT) model development progresses and new datasets become available, and is therefore subject to change. This memorandum was prepared in response to an Environmental Protection Agency (EPA) request for additional information on the mean concentration trend analysis presented at the February 28, 2013 EPA/CPG Model Collaboration Meeting.

DATASETS

The datasets include samples of the top 0.4 to 0.5 feet of sediment. For increased spatial coverage and data density, samples from a range of years were combined to create the datasets nominally termed 1995 and 2010. The "1995 dataset" consisted of samples collected

[1] The merged "1995 dataset" is limited to the interval RM 0.95 to RM 6.85, as discussed below.

between 1995 and 1999; and the "2010 dataset" included samples collected between 2007 and 2012. Table 1 lists the datasets used for each time period.

Samples flagged as "rejected" were removed, non-detect results were set to half of the detection limit, and duplicates were averaged.

DATA GROUPINGS AND ASSOCIATED REGIONS

The river contains a center channel and nearshore shoals. These major features were treated separately for purposes of concentration interpolation. The shoals have been termed Group 1 areas. The channel was subdivided based on the extent of historical erosion and deposition to account for corresponding trends in surface sediment 2,3,7,8-TCDD concentration. Figure 1 shows these trends for the interval from RM 2.5 to RM 6.8, based on bathymetric change between 1949/1950[2] and 2010. Concentrations are consistently low at locations that experienced little to no historical accumulation (termed Group 2), are highest and most variable at locations that experienced deposition up to about 4 to 6 feet (termed Group 3), and tend to be intermediate with less variability at locations that experienced more than 4 to 6 feet of deposition (termed Group 4). The deposition threshold between Group 3 and Group 4 was set to 6 feet between RM 2.5 and RM 4.4, and to 4 feet between RM 4.4 and RM 6.8 based on the longitudinal distribution of elevated concentrations and bathymetric change. The CPG has presented this grouping classification approach to EPA previously[3], and Figure 1 reflects the concepts developed in Mathew et al. (2012).

The channel downstream of RM 2.3 and upstream of RM 6.8 was designated as Group 4; surface concentrations in these areas tend to be similar in magnitude and variability to Group 4 areas between RM 2.3 and RM 6.8 (Figure 2). Between RM 2.3 and RM 2.5, the channel was delineated into the groups using 1966[4] to 2010 bathymetric differences, with 6 feet of deposition defining the threshold for Group 4.

[2] A combination of 1949 and 1950 bathymetry surveys were used to represent post-dredge conditions between RM 2.5 and RM 6.8.
[3] Moffatt & Nichol and Deltares (2011) was presented at an EPA/CPG modeling meeting in November 2011; Mathew et al. (2012) was presented at an EPA/CPG modeling meeting in June 2012. The groupings have evolved subsequently, but build on the concepts and approach developed therein.
[4] The 1966 bathymetry extends to RM 2.3, i.e., 0.2 miles beyond the 1949/1950 bathymetry.

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The Group 3 areas (moderate historical deposition) were divided into two subgroups because of an association between surface sediment 2,3,7,8-TCDD concentrations and changes in bathymetry from 1995 to 2012. The higher concentrations among the Group 3 samples in the 2010 dataset tended to be from locations that experienced 1 foot or more of net erosion between 1995 and 2012 (Figure 3). Consequently, Group 3a areas are regions with 1 foot or greater of erosion since 1995, and Group 3b areas are regions with less than 1 foot of erosion since 1995.

Outside of the channel, historical bathymetric data coverage is scarce due to the lateral limits of the surveys. These typically low energy areas were delineated using the EPA broad shoals and margins geomorphology (see SEI/HQI 2011). The surface sediment 2,3,7,8-TCDD concentrations in this grouping (Group 1) are shown in Figure 4.

A map of the resulting groupings can be seen in Figures 5a-e, and the groupings are summarized in Table 2.

INTERPOLATION

The areas of the channel mapped as Group 2 and Group 4 were assigned the average of the surface sediment 2,3,7,8-TCDD concentrations within the group. Averages were used here due to the lower variability within these groups (compared to the other groups) and the lack of strong spatial correlation. Group 4 data (high historical deposition) were divided into two subgroups for purposes of averaging, comprising areas upstream and downstream of RM 1.5 (Figure 2). RM 1.5 was approximately the upstream-most extent of the last dredging event in 1983; consequently, the historical infilling would differ at this break point, and the somewhat lower concentrations below RM 1.5 were partially attributed to this effect[5].

Thiessen polygons were used to interpolate concentrations within each of the remaining group/subgroup areas (i.e., Groups 1, 3a, and 3b). A Thiessen polygon is a way of assigning an area-of-influence to a sample location such that any point within a particular Thiessen polygon is closer to the Theissen's sample location than to any other sample location used to

[5] Based on CPG analysis of dredging records.

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generate the Thiessen polygons. For example, Thiessen polygons can be seen in the right shoal at the top of Figure 6a.

Group 1 was divided into two subgroups for interpolation, right shoal and left shoal. The left and right shoals were treated as individual subgroupings for interpolation to prevent data from influencing concentrations across the channel. Groups 3a and 3b were each interpolated separately. Thiessen polygons were created separately for each subgroup, and then clipped to the spatial extent of the corresponding subgroup[6].

The clipped Thiessen polygons were used together with the averages for Groups 2 and 4 to create continuous surface concentrations for each dataset. Figures 6a through 6e show the resulting concentration map for the 1995 dataset between approximately RM 1 and RM 7[7]. Figures 7a through 7e show the concentration map for the 2010 dataset, for the same longitudinal extent.

AREA-WEIGHTED AVERAGING

Area-weighted average concentrations were needed to assign concentrations to model grid cells[8] for use in the CFT model (not shown) and to evaluate trends in surface sediment 2,3,7,8-TCDD concentrations from 1995 to 2010. Figure 8 shows trends in 2,3,7,8-TCDD concentrations from 1995 to 2010 averaged in two ways. The first panel shows separate area-weighted averages by interpolation groupings. The second panel shows area-weighted average concentration by model-predicted deposition categories based on the CPG sediment transport model's predicted bathymetry changes in each model grid cell between 1995 and 2010. The highly depositional category represents cells with greater than 15 centimeters (cm) of predicted net deposition, the mildly depositional category represents between 0 and

[6] When overlaying and clipping the polygons for the individual subgroups, in some cases polygons may be split into two or more parts. In these cases, one or more of the split polygons will no longer be connected to the original sample location from which its concentration is derived.
[7] The extent of the 1995 dataset was limited to approximately RM 0.95 to RM 6.85. For model initial conditions, a complete surface was needed for 1995. The 2010 surface was used to represent 1995 concentrations outside the coverage of the 1995 dataset. Triangles representing the 2010 surface can be seen on the 1995 maps at the top of Figure 6a.
[8] The model grid cell layer did not precisely align with the true extents of the river due to resolution limitations. Only areas with overlap between the model grid cells and the interpolated layer were used in the calculation of an area-weighted average by model grid cell.

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15 cm of predicted net deposition, and the erosional category represents cells with predicted net erosion. The longitudinal extent of the comparison is approximately RM 0.95 to RM 6.85, based on the coverage of the merged 1995 dataset.

REFERENCES

SEI/HQI (Sea Engineering, Inc. and HydroQual, Inc.), 2011. Lower Passaic River: System Understanding of Sediment Transport. May 2011.

Moffatt & Nichol and Deltares, 2011. LPR Sediment Contamination Patterns and RCATOX Initial Conditions. Presented at the EPA/CPG Semi-Annual Modeling Meeting, November 15, 2011.

Mathew, R., D. Manian, R. Canizares, and J. Winterwerp, 2012. Estuarine Dynamics and Contaminant Distribution Patterns in the Lower Passaic River Study Area. Presented at the SMWG Spring Sponsor Forum, Newark, NJ, May 17, 2012 (also presented at the EPA/CPG Collaboration Meeting on June 12, 2012).

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TABLES

Table 1
Surface Sediment 2,3,7,8-TCDD Studies for RM 1-7

Study	Used in Dataset for
1995 RI Sampling Program	1995
1995 Surface Sediment Sampling Program	1995
1998 USEPA REMAP Sediment Investigation	1995
1999 Late Summer/Early Fall RI-ESP Sampling Program	1995
1999 Preliminary Toxicity Identification Evaluation Study	1995
1999-2000 Minish Park Monitoring Program	1995
2007-2008 Sediment Sampling Program[1]	2010
2008 CPG Low-resolution Coring Program	2010
2009-2010 RI FSP2 Benthic Sediment Sampling	2010
2012 CPG Supplemental Sampling Program	2010

Notes:

1. From this dataset, only samples collected in 2008 fell within RM 1-7.

CPG = Cooperating Parties Group
ESP = Ecological Sampling Plan
FSP = Field Sampling Plan
REMAP = Regional Environmental Monitoring and Assessment Program
RI = Remedial Investigation
RM = River Mile
TCDD = 2,3,7,8-tetrachlorodibenzo-p-dioxin
USEPA = U.S. Environmental Protection Agency

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Table 2
Summary of Interpolation Groups

Group	Description	Spatial Extent	Sub-group	Sub-group Spatial Extent	Interpolation Method
1	Shoals (low energy areas)	USEPA Geomorphology "broad shoals" and "margins"	Left shoal	Left side of the river	Thiessen polygons
			Right shoal	Right side of the river	Thiessen polygons
2	Little to no historical deposition, associated with low surficial 2,3,7,8-TCDD concentrations	Bathymetry-based sedimentation: 2010 bathymetry deeper than 1966 bathymetry (RM 2.3 to 2.5) 2010 bathymetry deeper than 1949/1950 bathymetry (RM 2.5 to 6.8)	-	-	Average concentration
3	Moderate historical deposition, associated with intermediate to high surficial 2,3,7,8-TCDD concentrations	Bathymetry-based sedimentation: from 1966 to 2010 of 0-6 feet (RM 2.3 to 2.5) from 1949/1950 to 2010 of 0-6 feet (RM 2.5 to 4.4) from 1949/1950 to 2010 of 0-4 feet (RM 4.4 to 6.8)	Group 3a	≥ 1 foot of erosion from 1995 to 2012 based on bathymetry	Thiessen polygons
			Group 3b	< 1 foot of erosion from 1995 to 2012 based on bathymetry	Thiessen polygons
4	High historical deposition, associated with intermediate surficial 2,3,7,8-TCDD concentrations	Bathymetry-based sedimentation: from 1966 to 2010 of >6 feet (RM 2.3 to 2.5) from 1949/1950 to 2010 of >6 feet (RM 2.5 to 4.4) from 1949/1950 to 2010 of >4 feet (RM 4.4 to 6.8) All channel areas from RM 0 to 2.3 and from RM 6.8 and 7.5	Group 4 RM 1.5 to 7.5	RM 1.5 to 7.5	Average concentration
			Group 4 RM 0.0 to 1.5	RM 0 to 1.5	Average concentration

Notes:
RM = River Mile
TCDD = tetrachlorodibenzo-p-dioxin
USEPA = U.S. Environmental Protection Agency

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FIGURES

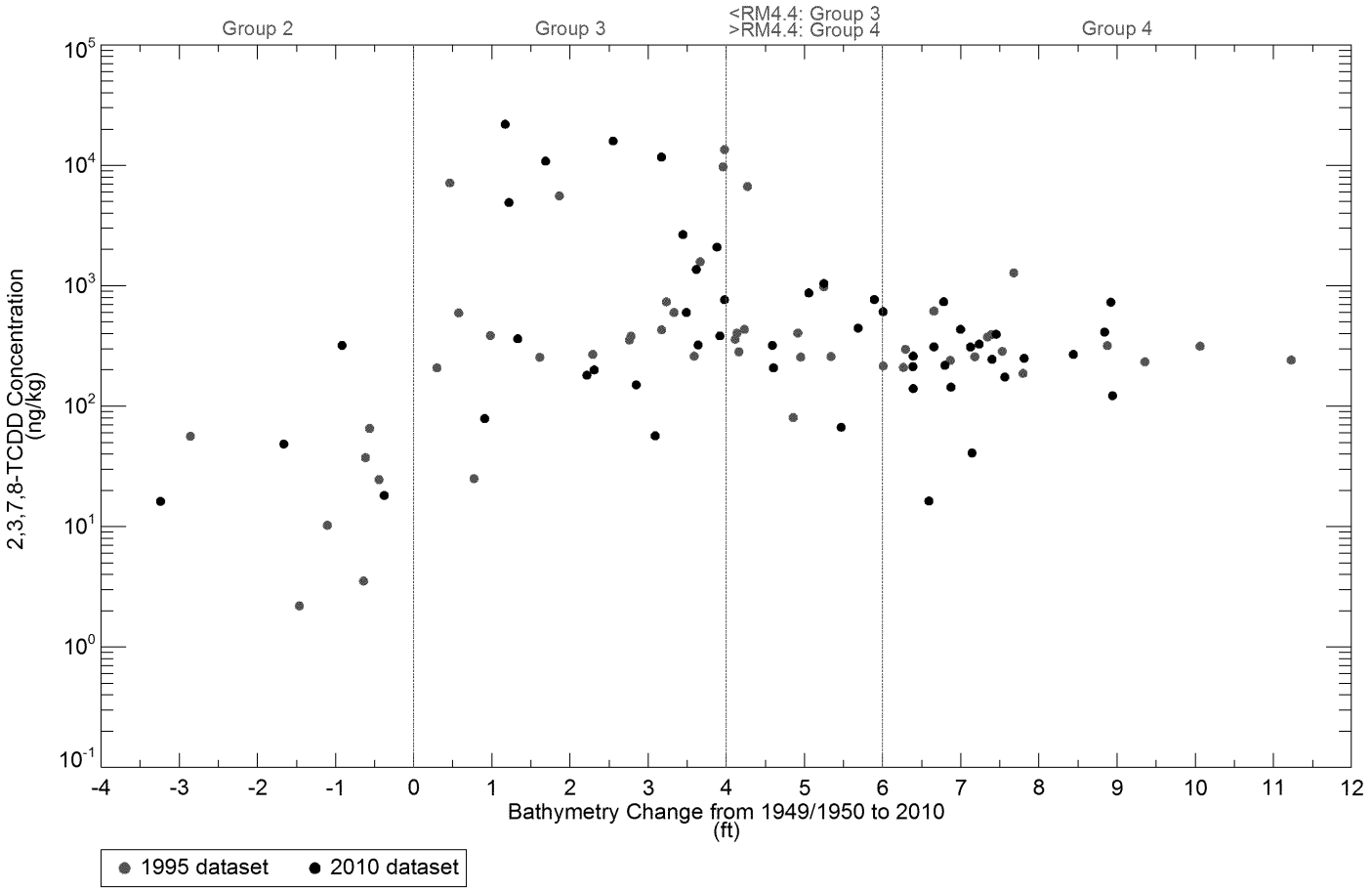

Figure 1

Surface Sediment 2,3,7,8-TCDD Concentration vs Historical Sedimentation in the Channel (RM 2.5 to RM 6.8)

The comparison is limited to RM 2.5 to RM 6.8, based on 1949/1950 bathymetry survey coverage.
Figure developed from Mathew et al. (2012).

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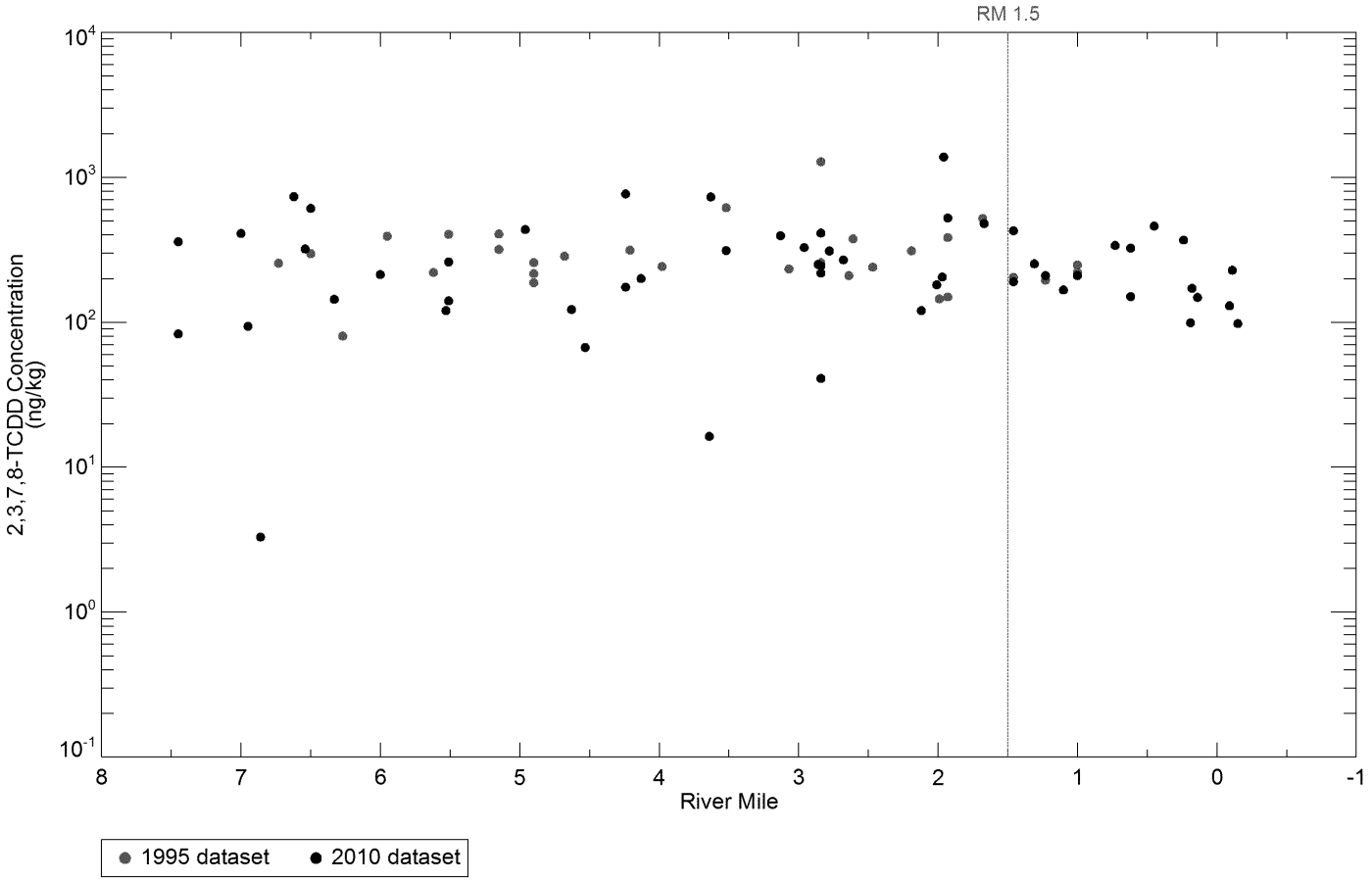

Figure 2

Group 4 Surface Sediment 2,3,7,8-TCDD Concentration vs. LPR River Mile

Figure GHM-CRSHG from Mathew et al.(2012).

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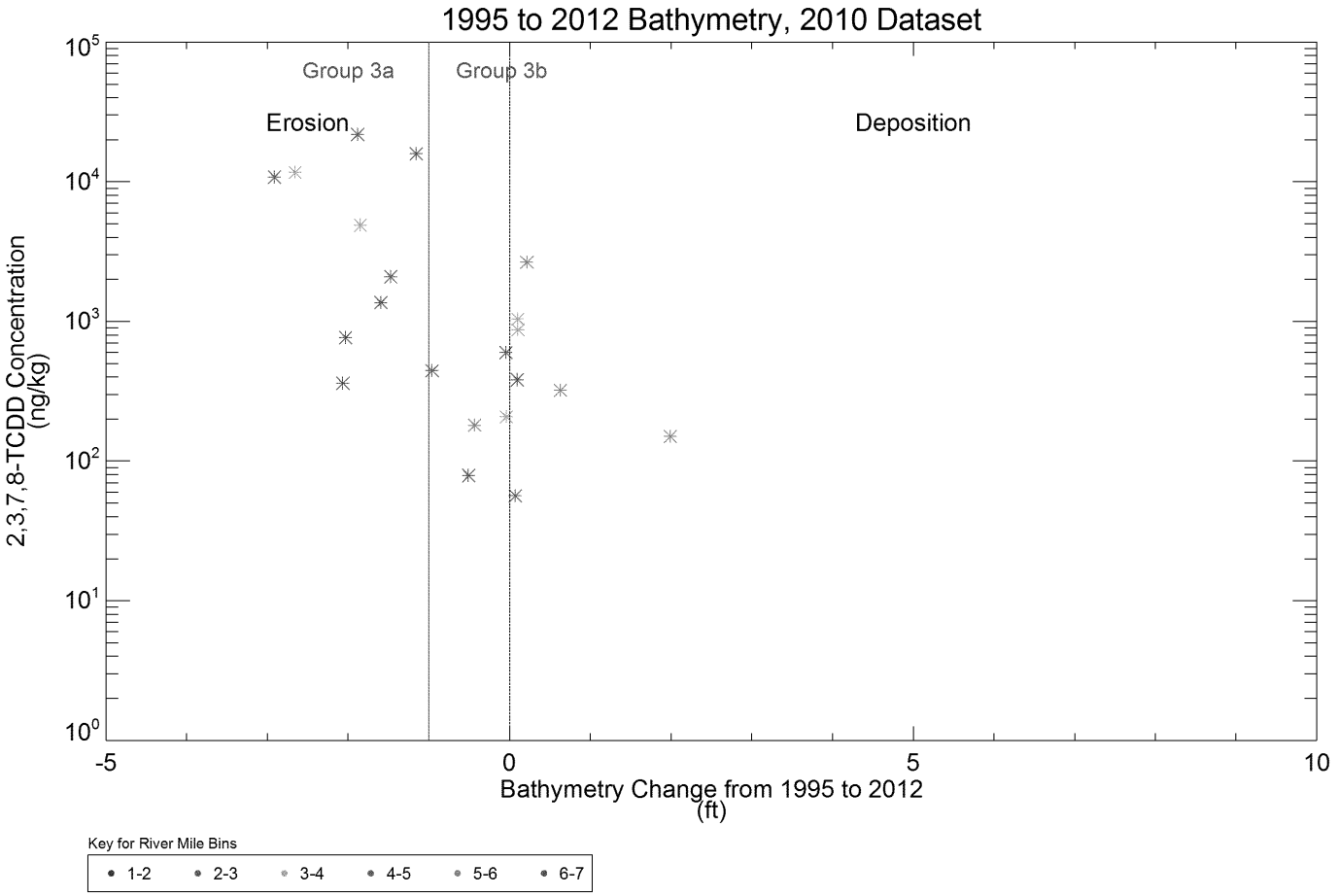

Figure 3

Group 3 Surface Sediment 2,3,7,8-TCDD Concentration vs. Bathymetry Change from 1995 to 2012

Red line represents split of Group 3 into 3a and 3b at -1.0 ft bathymetry change.
2012 Bathymetry from multi-beam data. 1995 Bathymetry from single-beam data.
The 2010 2,3,7,8-TCDD surface concentration dataset includes studies in Table 1.

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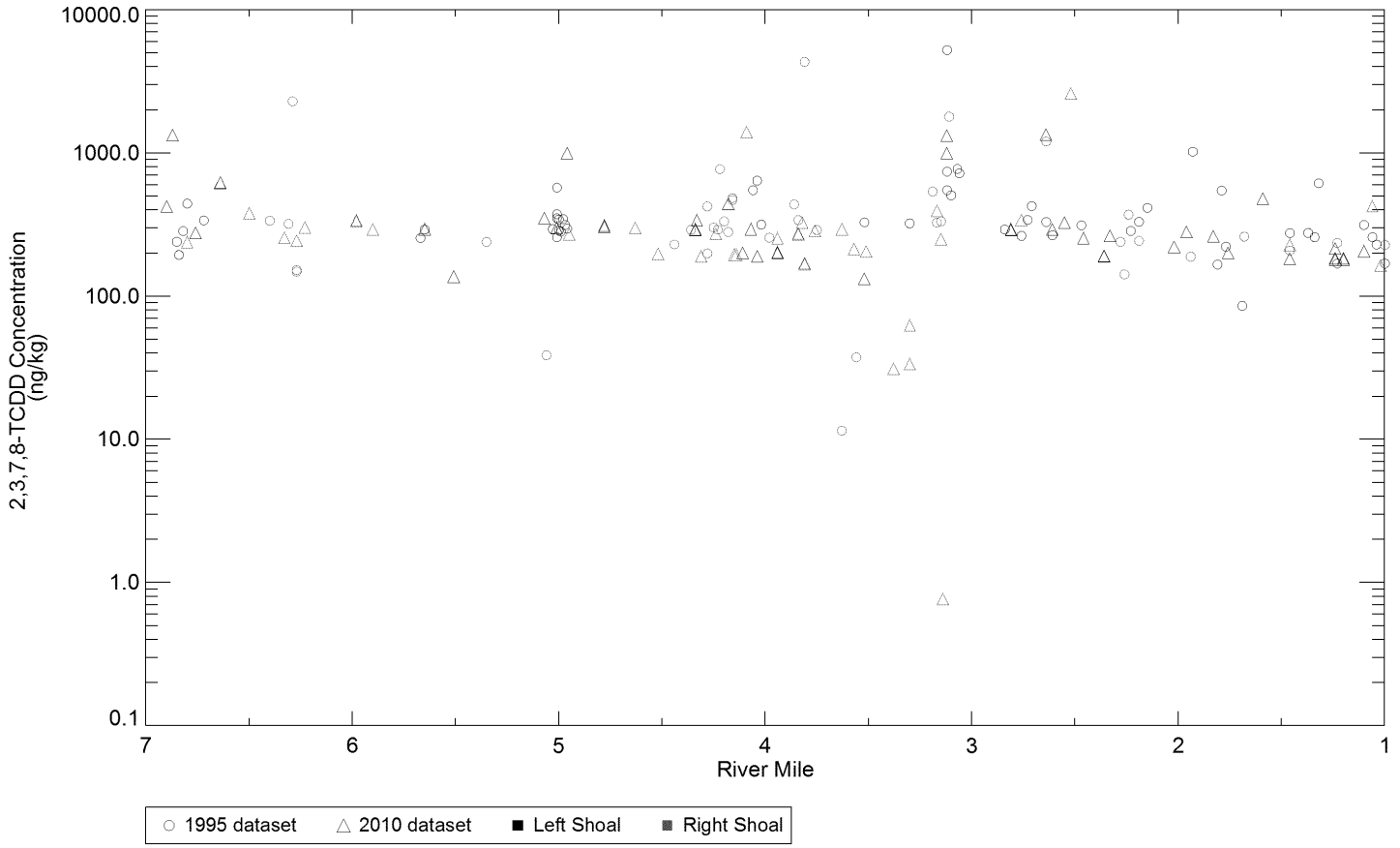

Figure 4

Group 1 Surface Sediment 2,3,7,8-TCDD Concentrations vs. River Mile

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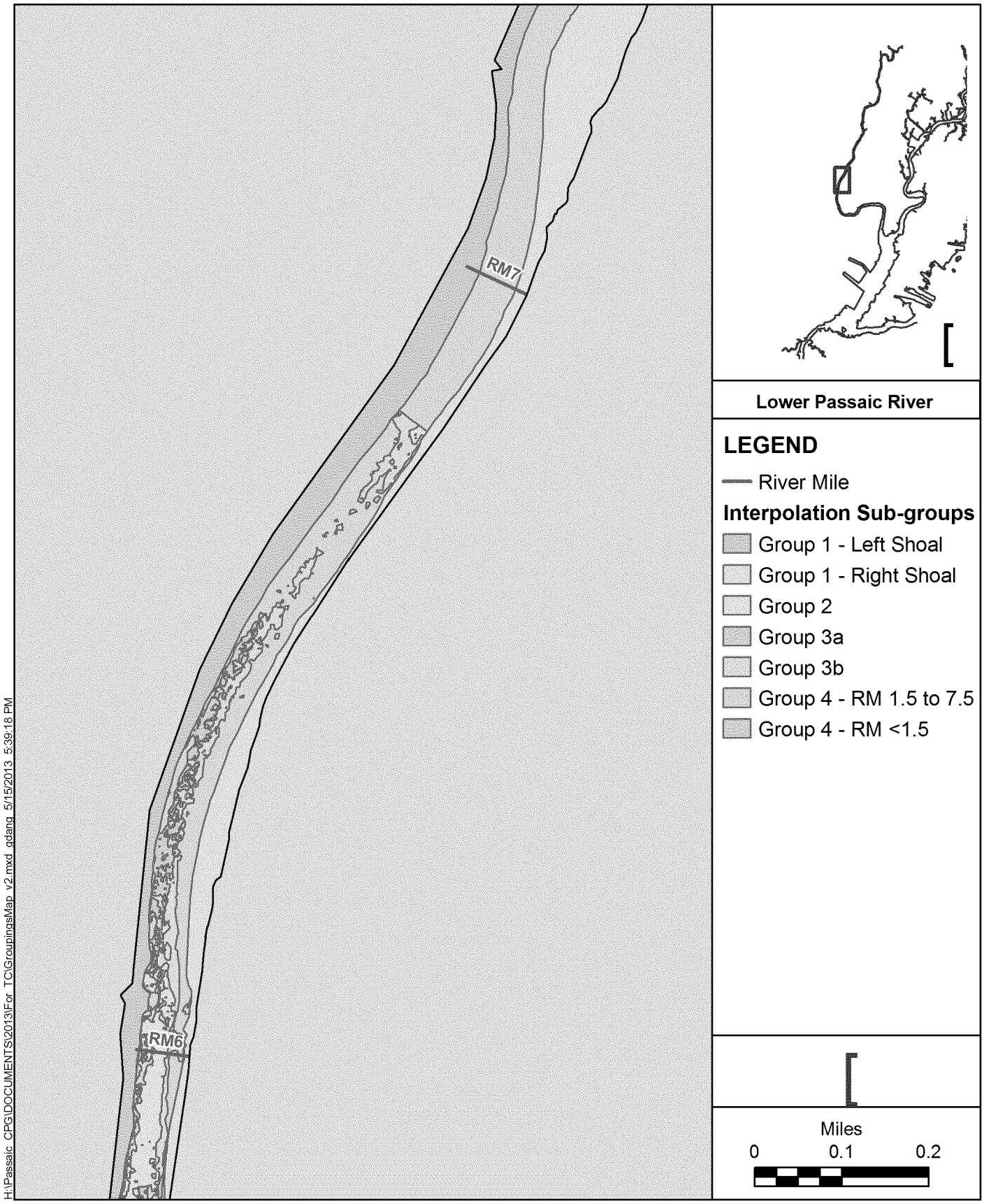

Figure 5-a
Surface Concentration Interpolation Groupings
Lower Passaic River Concentration Mapping

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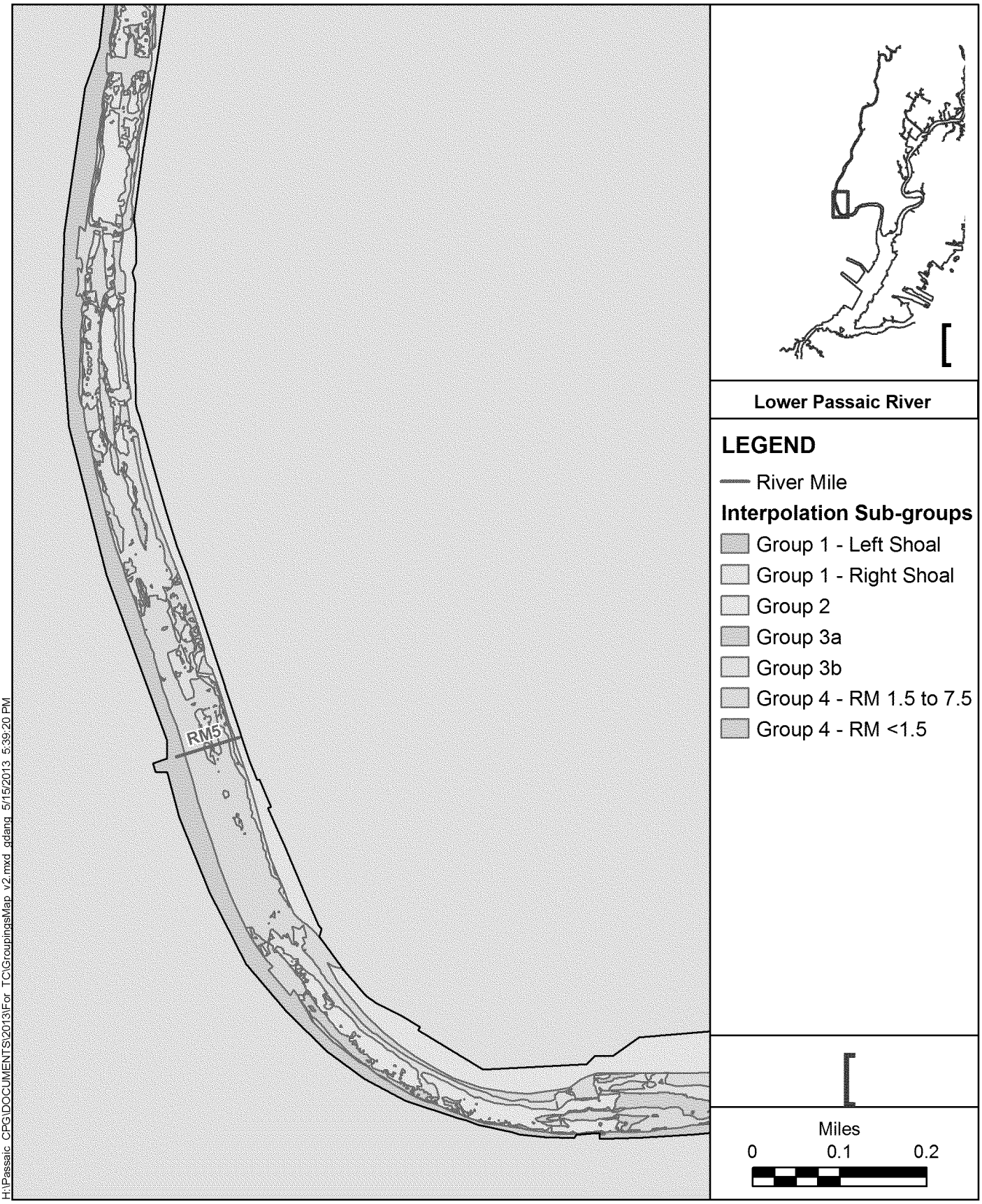

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Figure 5-b
Surface Concentration Interpolation Groupings
Lower Passaic River Concentration Mapping

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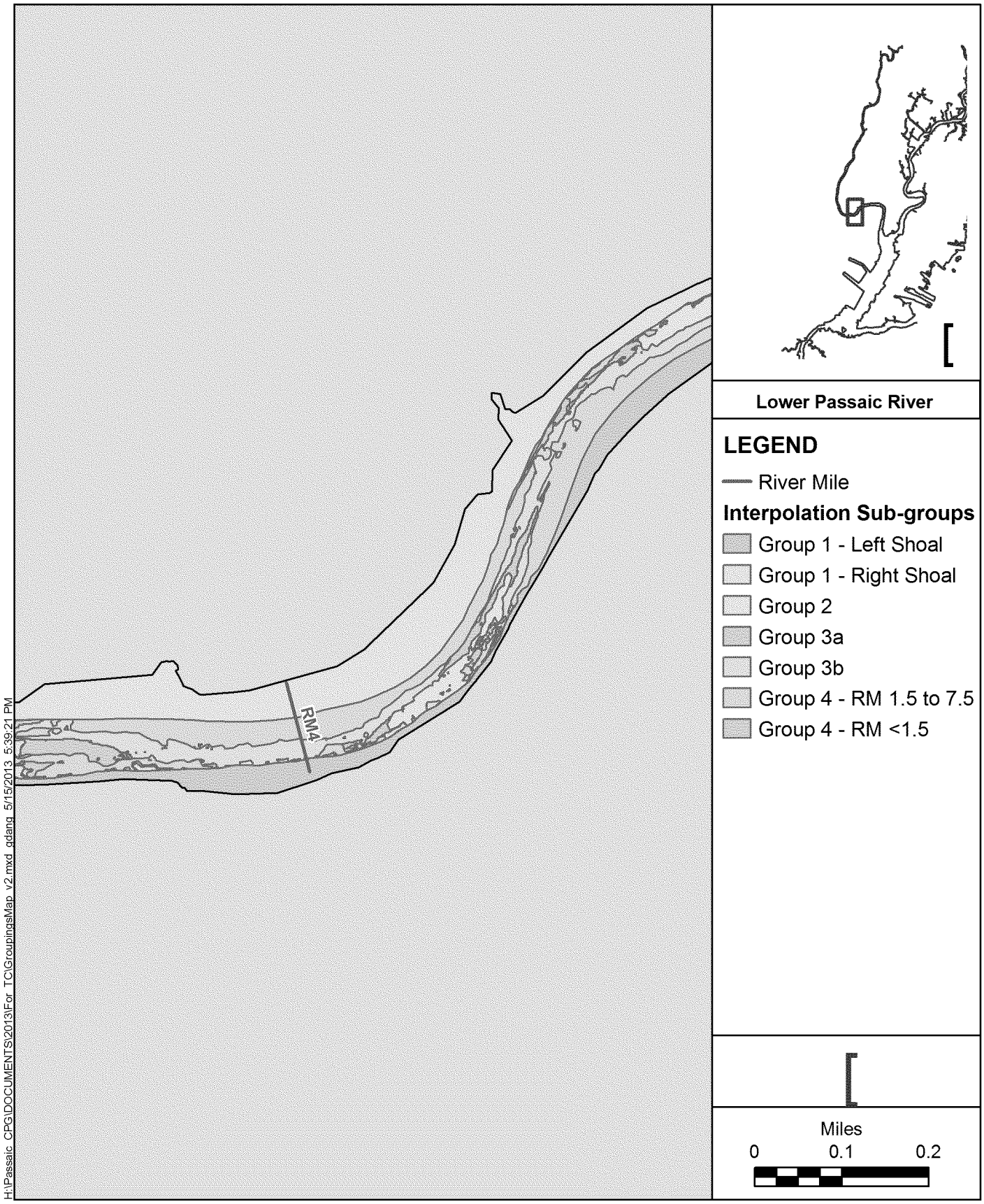

Figure 5-c
Surface Concentration Interpolation Groupings
Lower Passaic River Concentration Mapping

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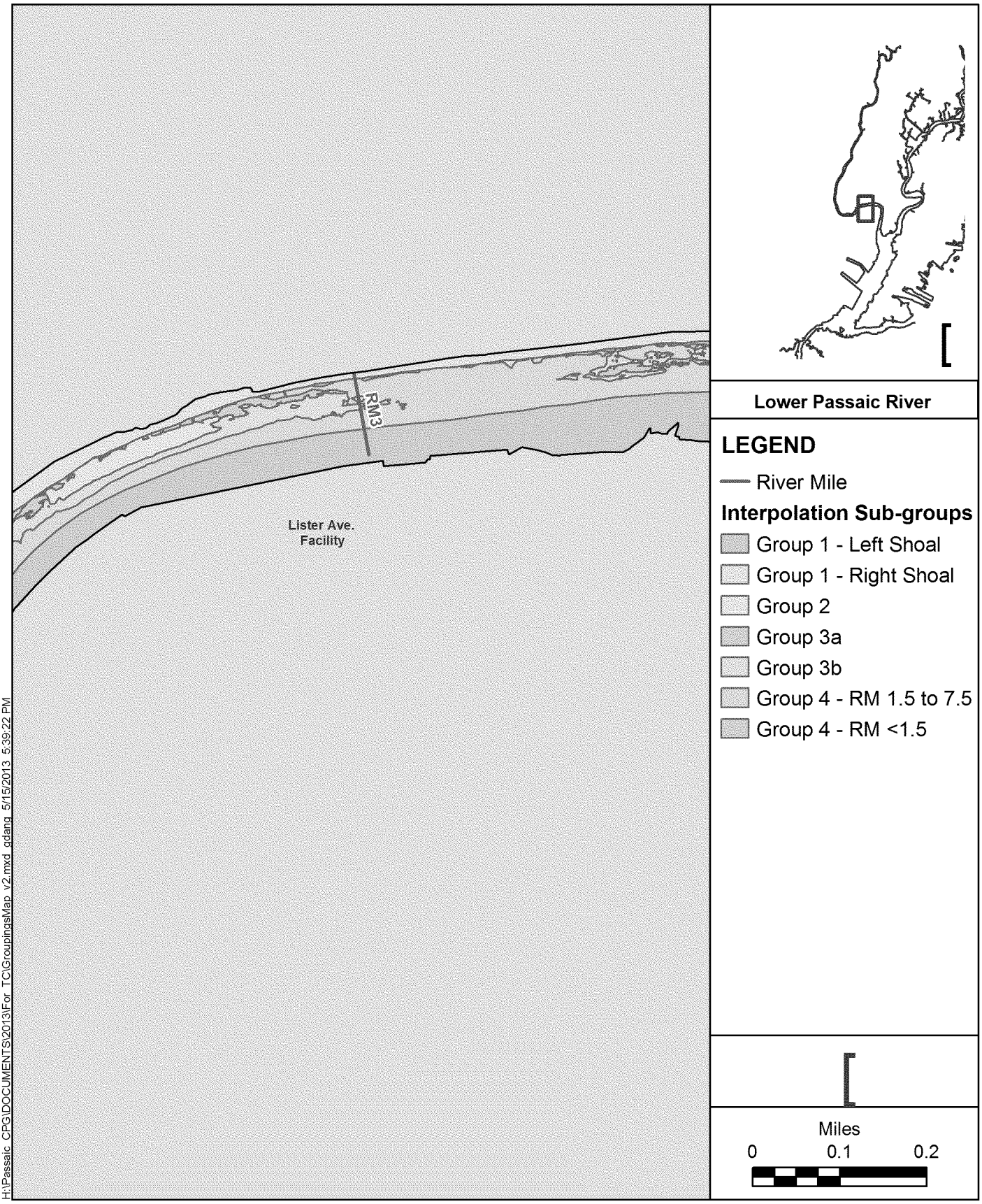

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Figure 5-d
Surface Concentration Interpolation Groupings
Lower Passaic River Concentration Mapping

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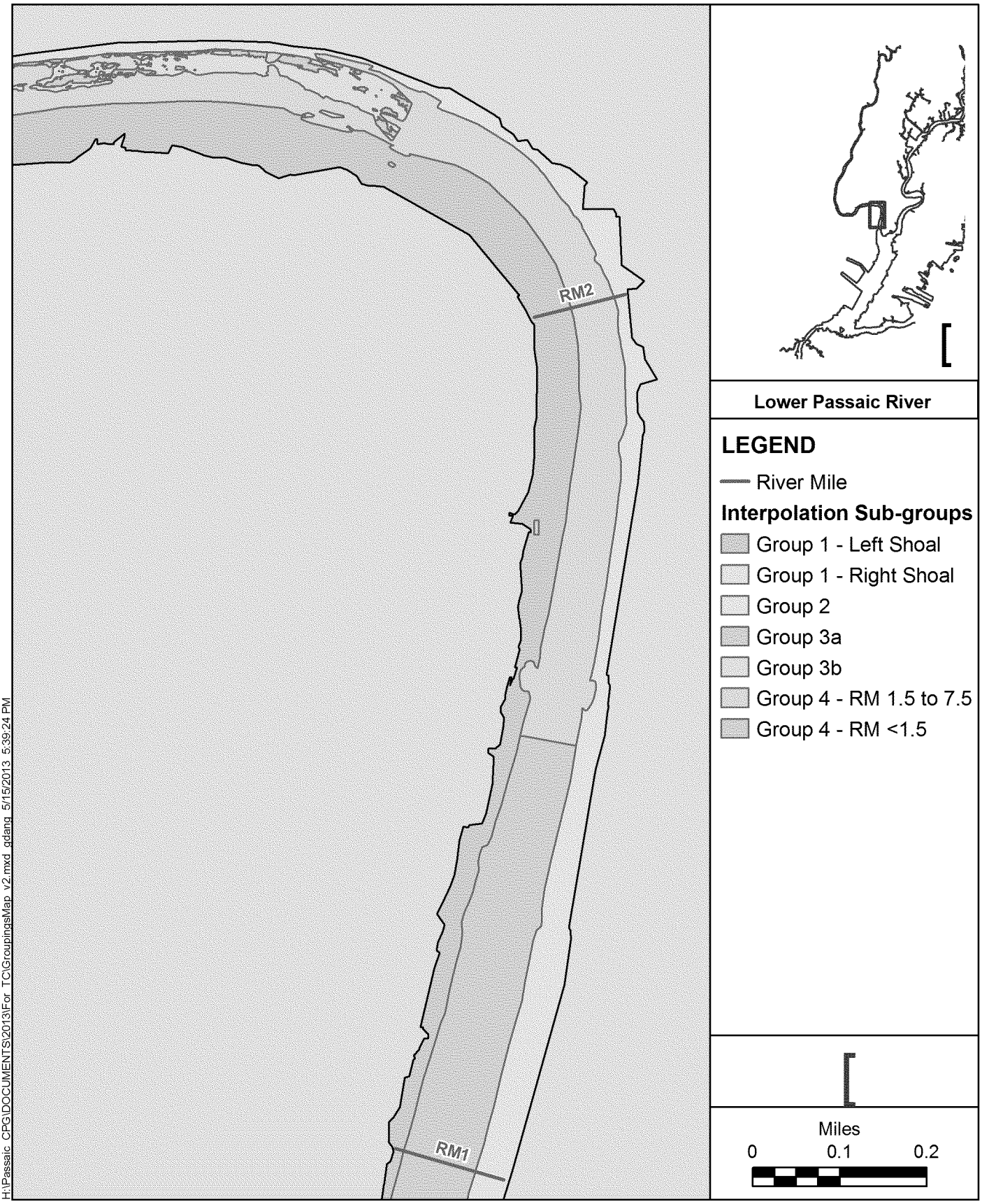

Figure 5-e
Surface Concentration Interpolation Groupings
Lower Passaic River Concentration Mapping

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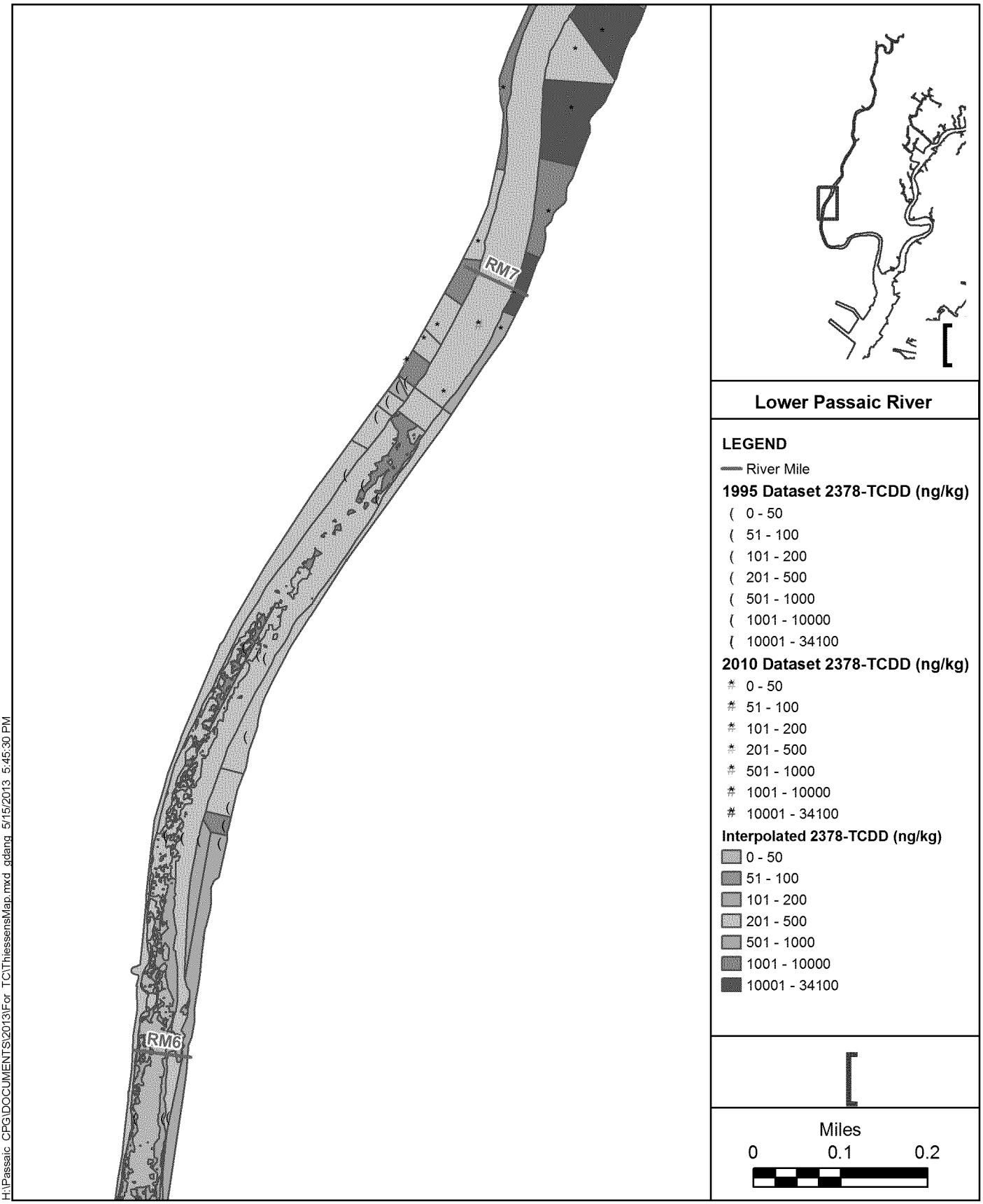

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Figure 6-a

1995 Dataset: Interpolated 2,3,7,8-TCDD Surface Sediment Concentrations
Lower Passaic River Concentration Mapping

ANCHOR QEA

The 1995 dataset is composed of cores sampled between 1995-1999.
The 2010 dataset is composed of cores sampled between 2007-2012.
2010 dataset is used upstream of RM 6.85 where 1995 data are not available.

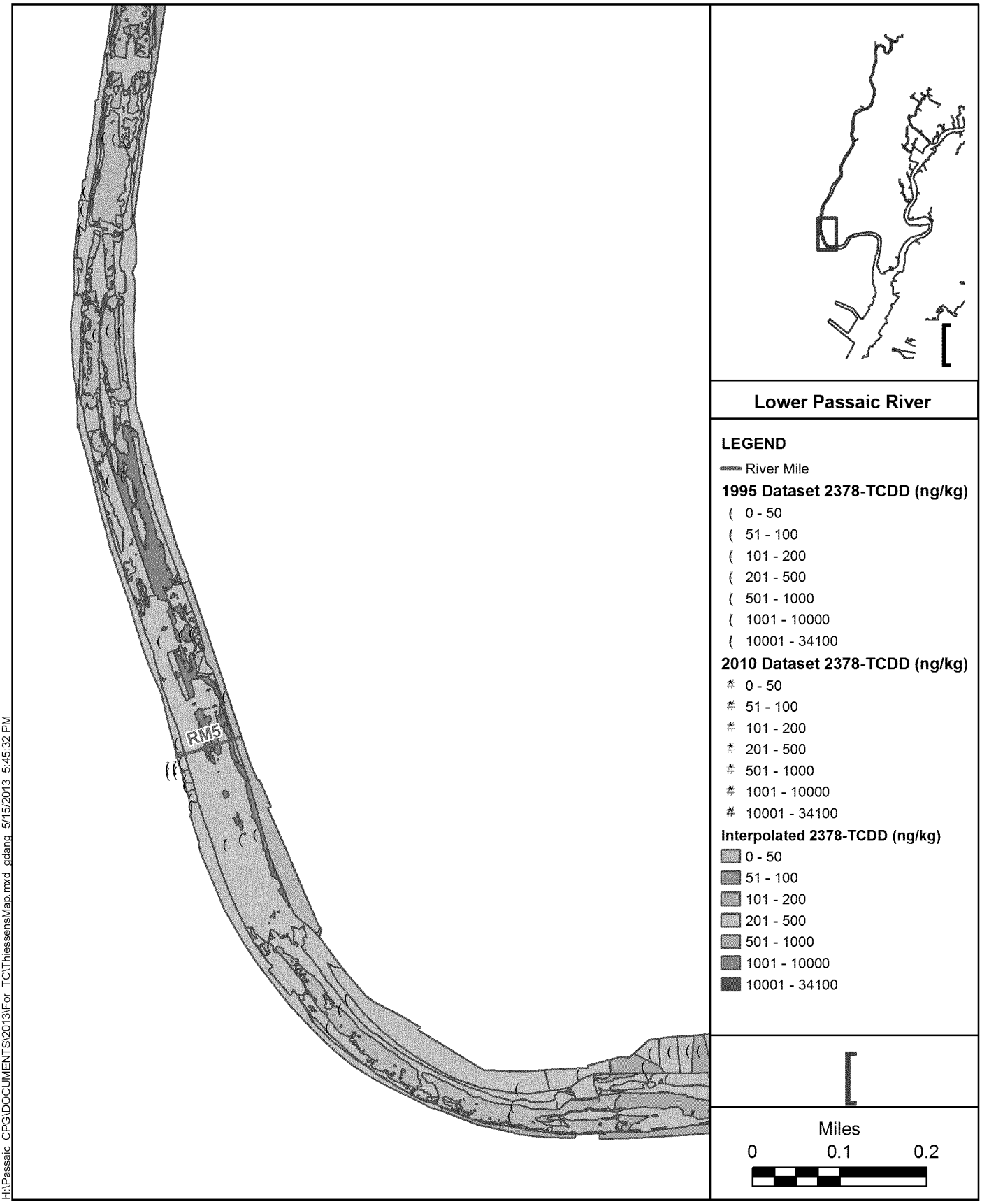

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Figure 6-b

1995 Dataset: Interpolated 2,3,7,8-TCDD Surface Sediment Concentrations
Lower Passaic River Concentration Mapping

ANCHOR QEA

The 1995 dataset is composed of cores sampled between 1995-1999.
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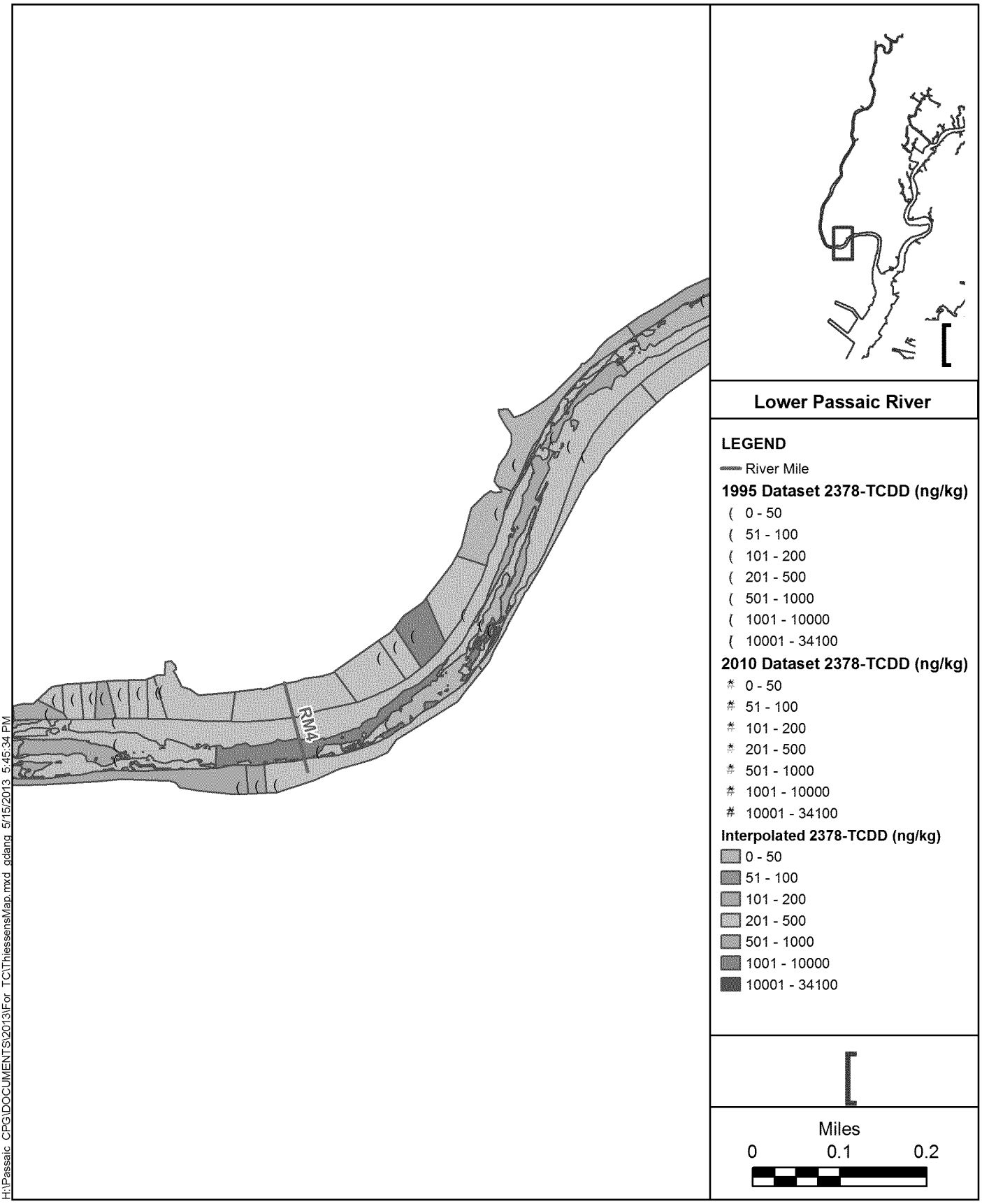

Figure 6-c

1995 Dataset: Interpolated 2,3,7,8-TCDD Surface Sediment Concentrations
Lower Passaic River Concentration Mapping

ANCHOR QEA

The 1995 dataset is composed of cores sampled between 1995-1999.
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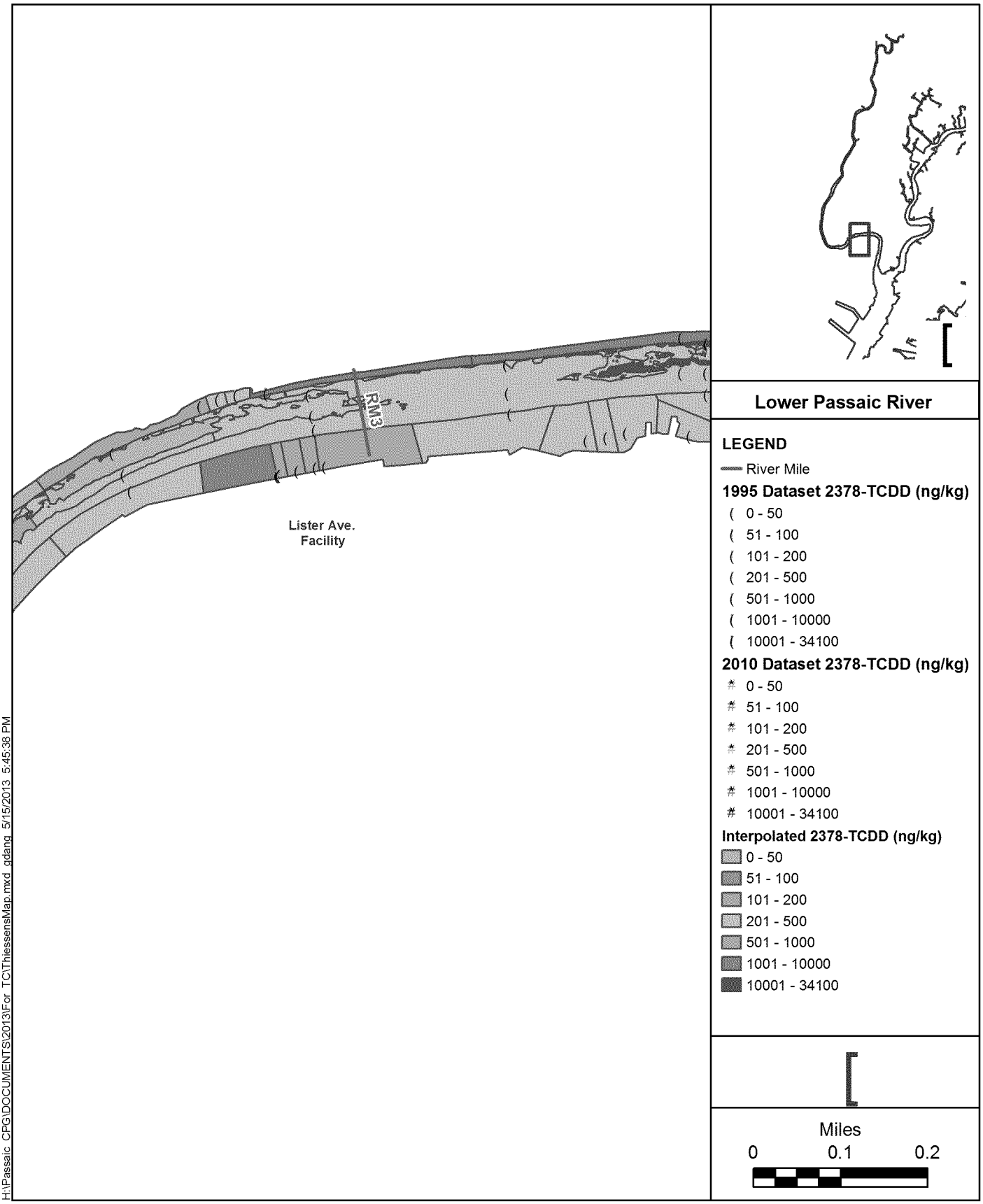

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Figure 6-d

1995 Dataset: Interpolated 2,3,7,8-TCDD Surface Sediment Concentrations
Lower Passaic River Concentration Mapping

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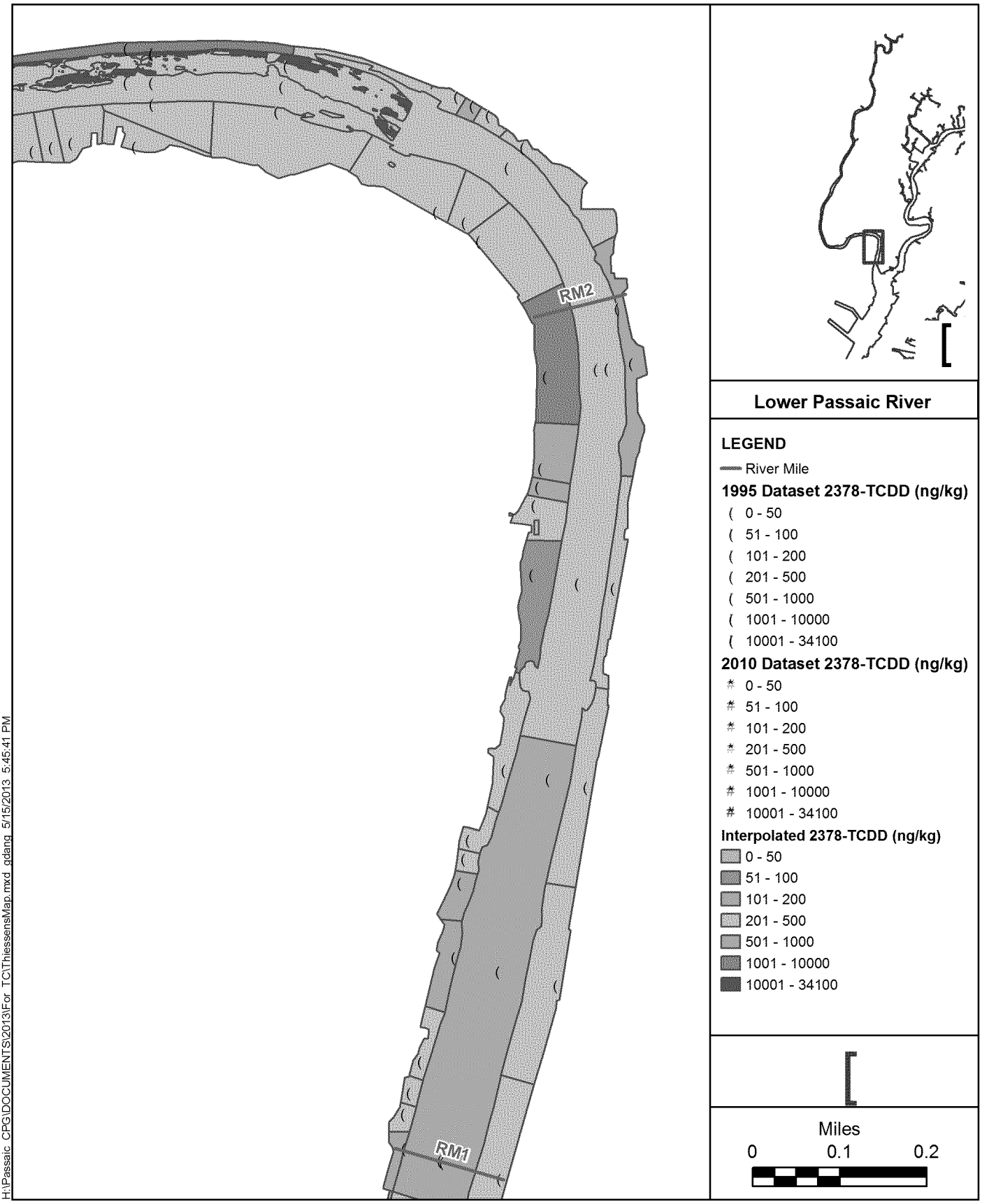

Figure 6-e

1995 Dataset: Interpolated 2,3,7,8-TCDD Surface Sediment Concentrations
Lower Passaic River Concentration Mapping

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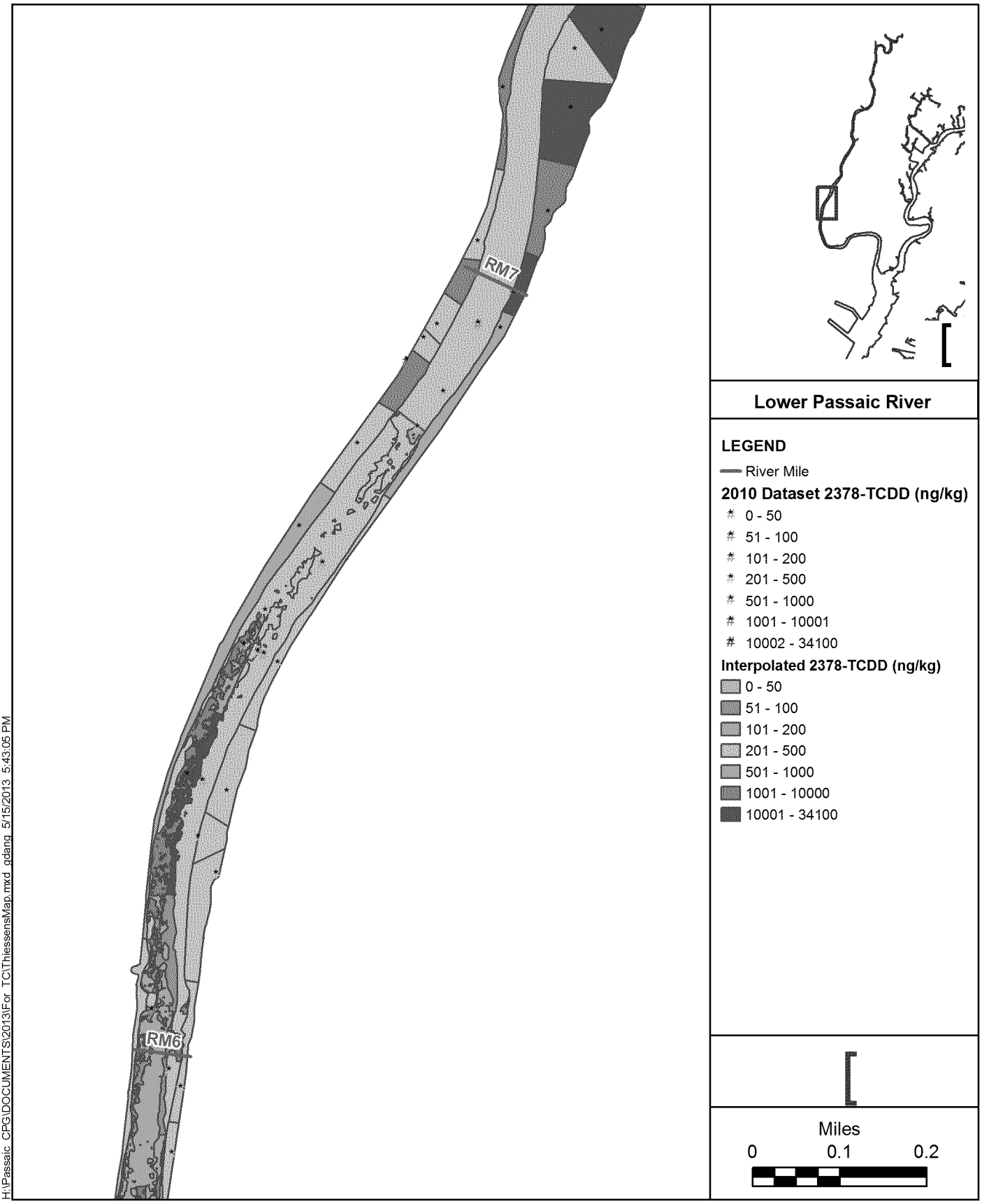

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Figure 7-a

2010 Dataset: Interpolated 2,3,7,8-TCDD Surface Sediment Concentrations
Lower Passaic River Concentration Mapping

The 2010 dataset is composed of cores sampled between 2007-2012.

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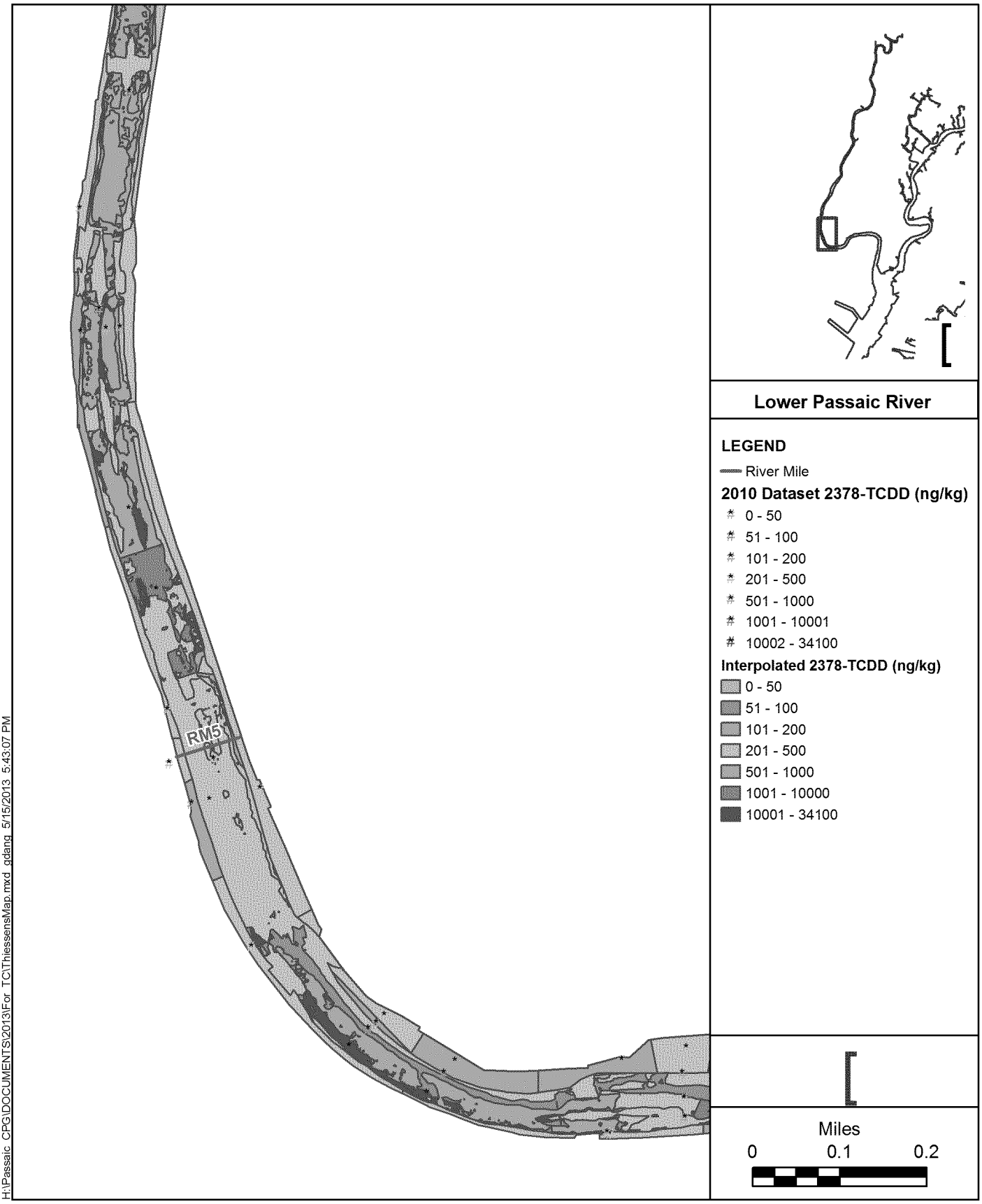

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Figure 7-b

2010 Dataset: Interpolated 2,3,7,8-TCDD Surface Sediment Concentrations
Lower Passaic River Concentration Mapping

The 2010 dataset is composed of cores sampled between 2007-2012.

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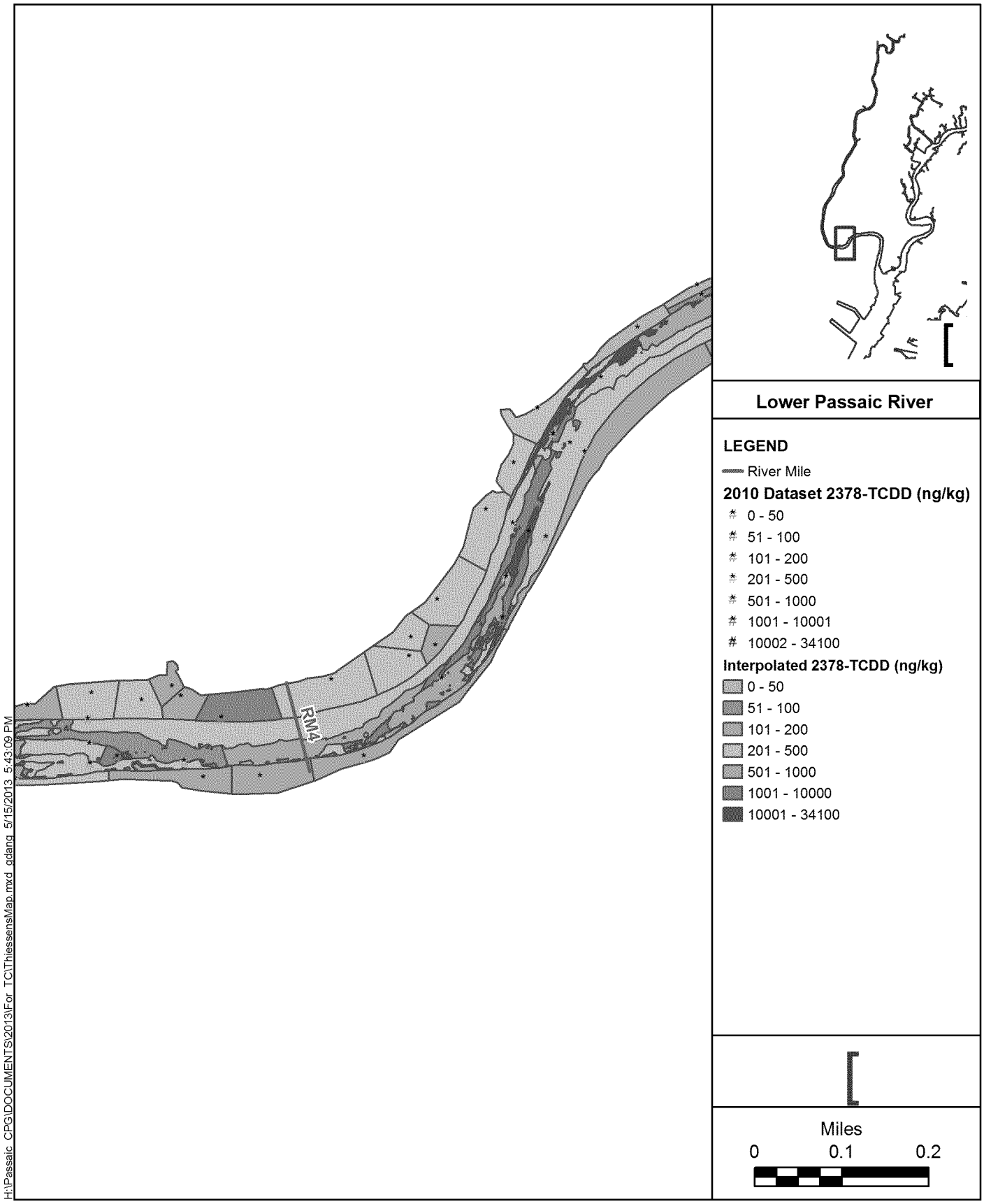

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Figure 7-c

2010 Dataset: Interpolated 2,3,7,8-TCDD Surface Sediment Concentrations
Lower Passaic River Concentration Mapping

The 2010 dataset is composed of cores sampled between 2007-2012.

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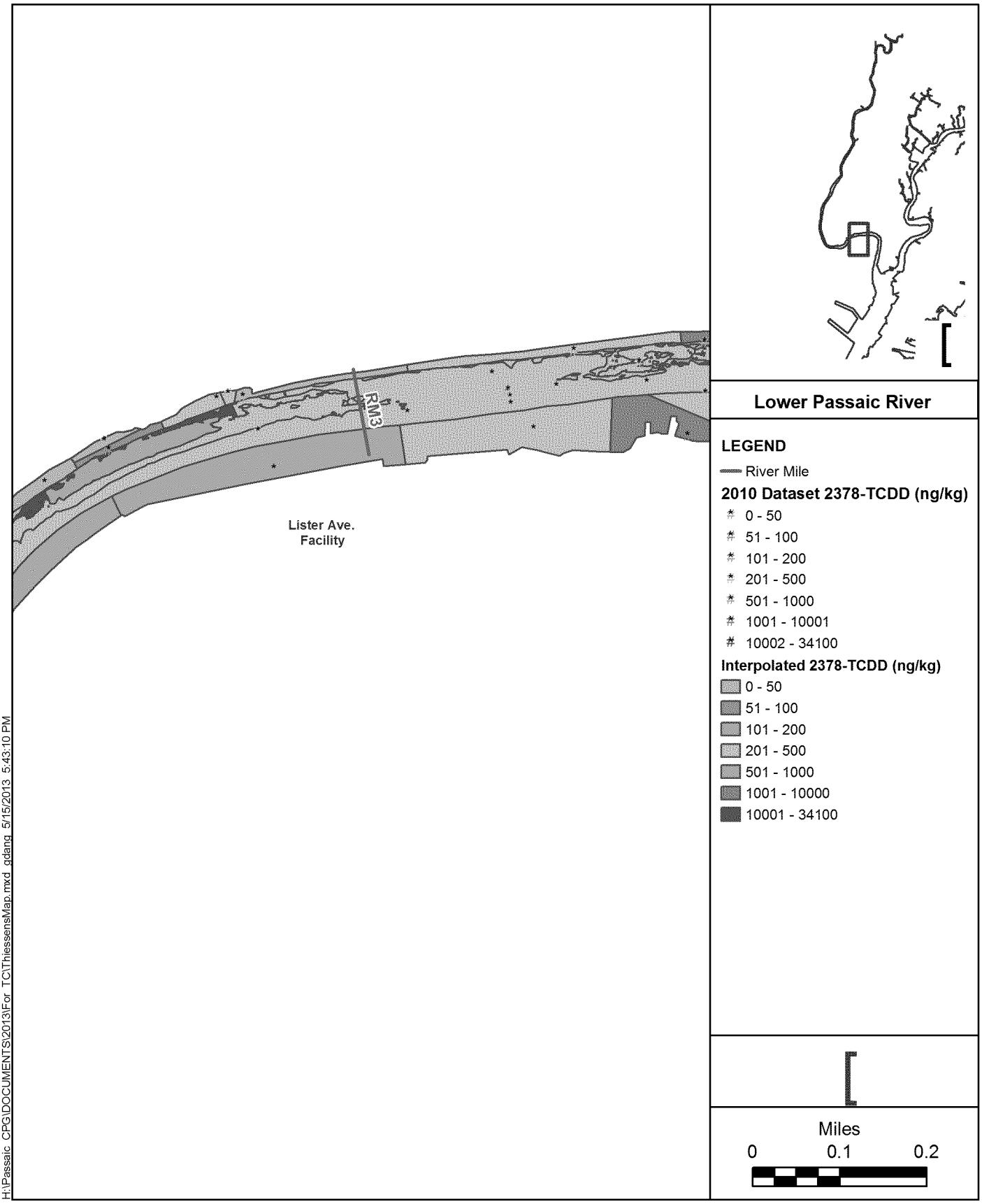

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Figure 7-d

2010 Dataset: Interpolated 2,3,7,8-TCDD Surface Sediment Concentrations
Lower Passaic River Concentration Mapping

The 2010 dataset is composed of cores sampled between 2007-2012.

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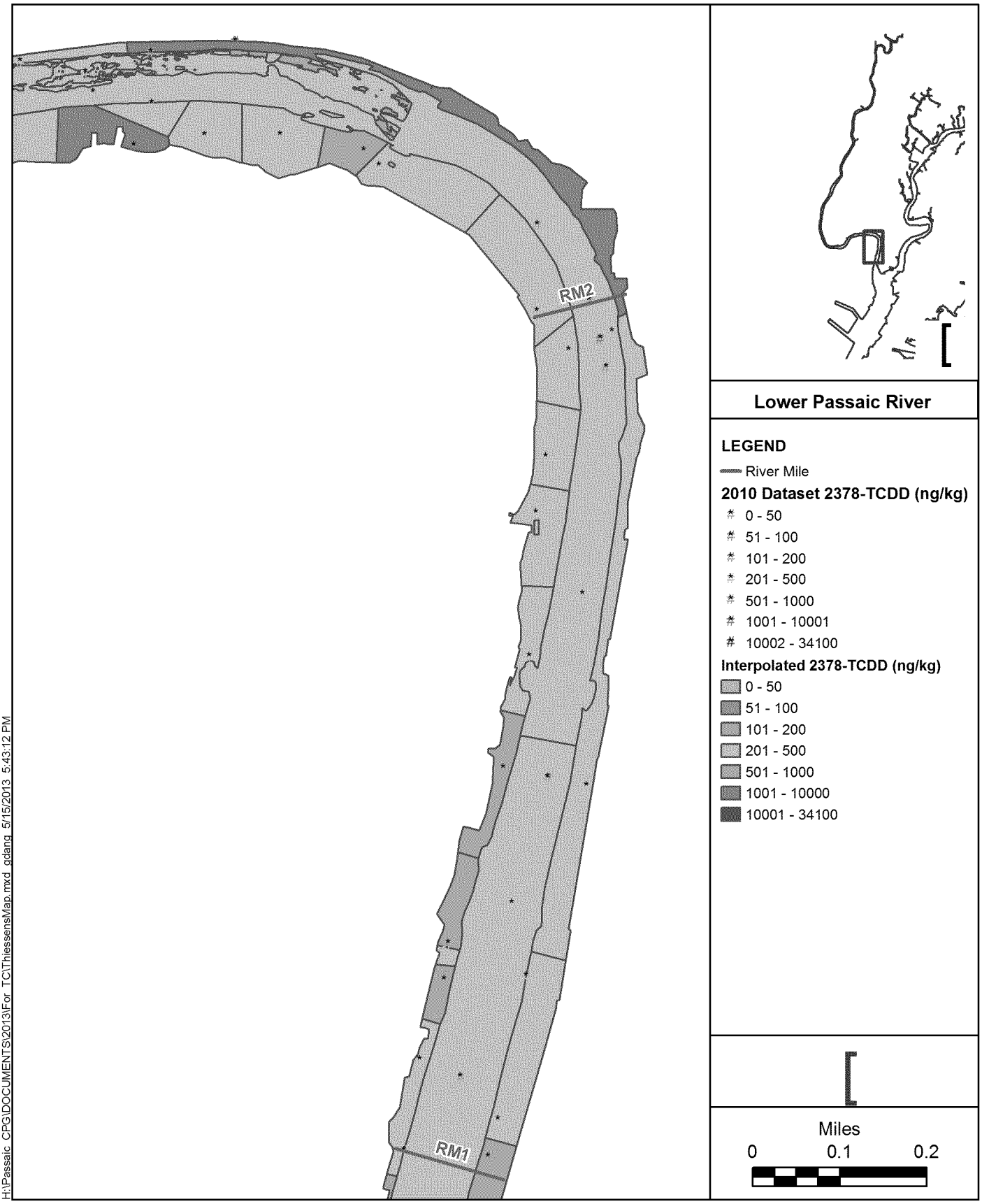

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Figure 7-e

2010 Dataset: Interpolated 2,3,7,8-TCDD Surface Sediment Concentrations
Lower Passaic River Concentration Mapping

The 2010 dataset is composed of cores sampled between 2007-2012.

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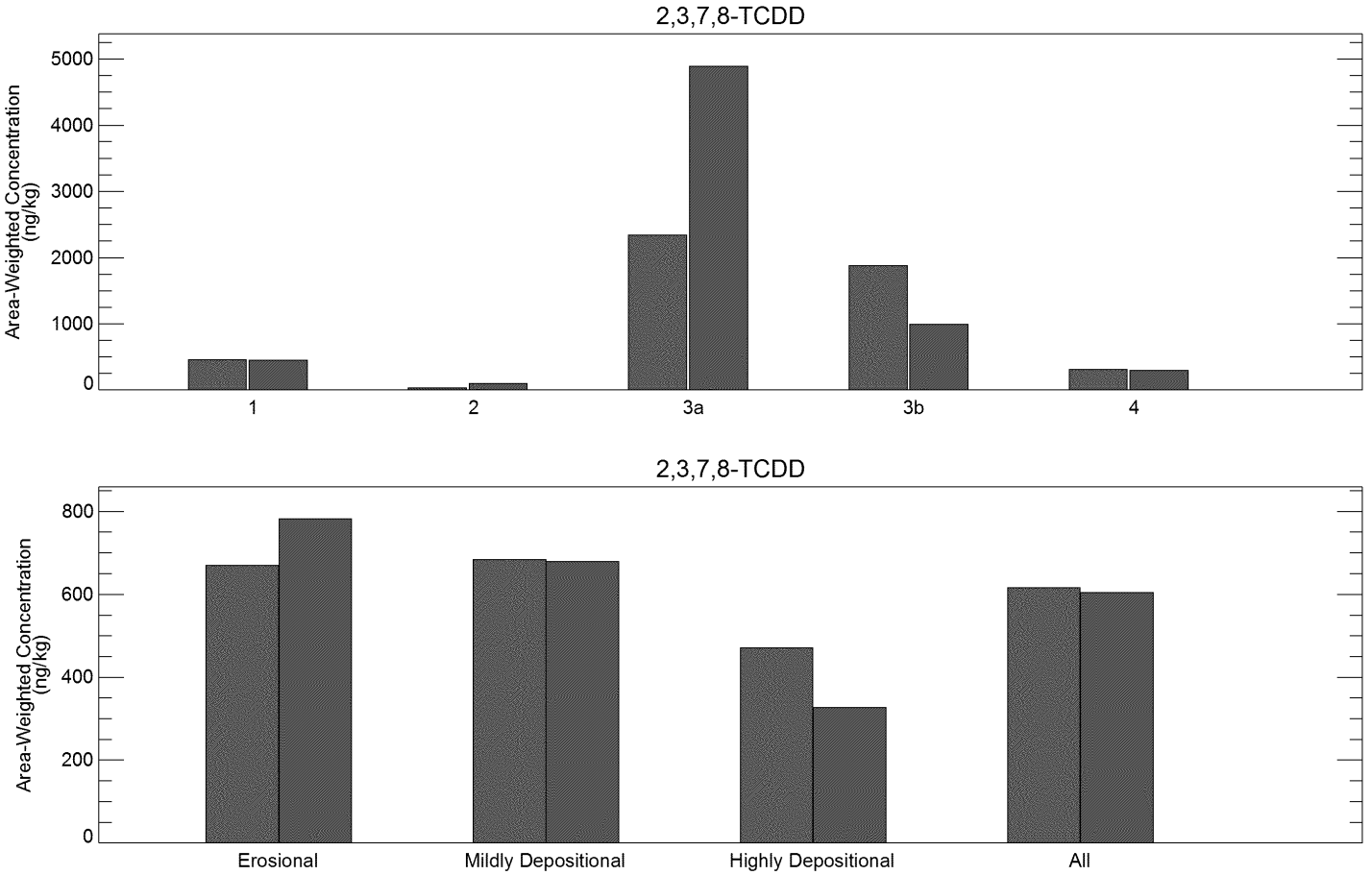

Figure 8

Area-Weighted Surface Sediment 2,3,7,8-TCDD Concentrations by Interpolation Groups and Model Predicted Deposition Regimes Between Approximately RM 1 to 7

- 1995 merged dataset
- 2010 merged dataset

Lower Passaic River Concentration Mapping

The averaging interval extends from RM 0.95 to RM 6.85, based on the extents of the merged 1995 dataset.

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Wed May 15 17:35:20 2013