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Wetland Ecology Group
Division of Surface Water

ASSESSMENT OF WETLAND MITIGATION PROJECTS IN OHIO

VOLUME 1: AN ECOLOGICAL ASSESSMENT OF OHIO INDIVIDUAL WETLAND MITIGATION PROJECTS

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VOLUME 1: AN ECOLOGICAL ASSESSMENT OF OHIO INDIVIDUAL WETLAND MITIGATION PROJECTS

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ABSTRACT

A randomly selected group of individual wetland mitigation projects from around Ohio were studied to determine their ecological performance. Projects were stratified by the number of years since construction and were put into groups of five year intervals. Those groups were: less than five years since construction ("recent"); five to ten years since construction ("middle"); and more than ten years since construction ("old"). Twenty-six projects were randomly selected and monitored, seven were from the recent group, ten were from the middle group and nine were from the old group. Wetlands were monitored for the ecological condition using the Vegetation Index of Biotic Integrity (VIBI) and the Amphibian Index of Biotic Integrity (AmphIBI). Automatic water level recorders were deployed at each wetland and the data was used to develop hydrographs. Landscape Development Intensity Index (LDI) scores for the areas surrounding the study wetlands, both at 100 meters and 100 to 350 meters were calculated. Two sites did not meet wetland criteria, as no significant plant communities of any kind had developed. For all 26 mitigation projects, VIBI scores had a mean of 34.35, which was significantly different than the mean for a group of Ohio natural reference wetlands that span the range of human disturbance. VIBI scores found 38.5% (10 sites) of the 24 mitigation wetlands monitored to be in poor ecological condition, 42.3% (11 sites) were in fair ecological condition, and 19.2% (5 sites) were in good ecological condition. There were not significant differences between mean VIBI scores for mitigation wetlands based on age classes. There were also no significant differences between VIBI score means for mitigation wetlands in high or low intensity surrounding land uses based on LDI scores at both 100 meters and 100 to 350 meters. However, overall VIBI scores were higher for natural wetlands surrounded by low intensity land uses both at 100 meters and 100 to 350 meters. AmphIBI scores for the 24 projects monitored found 87.5% (21 sites) of the mitigation projects to be in poor ecological condition, 8.3% (2 sites) were in fair ecological condition and 4.2% (1 site) were in excellent ecological condition. There were not significant differences between mean AmphIBI scores based on age classes although the middle age group AmphIBI scores were, on average, higher than the other two age groups. There were no correlations between AmphIBI scores and LDI scores at either 100 meters or 100 to 350 meters as AmphIBI scores were uniformly low. Overall, based on VIBI and/or AmphIBI evaluations, of the 26 individual wetland mitigation projects 61.5% (16 sites) are considered failures, 15.38% (4 sites) are considered potential successes and 23.08% (6 sites) are considered successes. Reasons for successes and failures are discussed.

Introduction

An important component of a successful wetland regulatory program is ensuring that any wetland impacts authorized are being adequately replaced. A fundamental assumption of wetland permit issuance is that the ecological condition, functions and services of the lost wetlands can be reconstructed at new sites. In fact, a key directive from a national prospective has been the no-net-loss policy for wetland programs. This approach targets no-net-loss of functions, ecological services and conditions as well as area (NRC 2001).

Past studies of Ohio individual wetland mitigation projects (Porej 2003, Kettlewell 2005) reveal that 71.2% of the acreage required in permit conditions is being provided. Although mitigation has not resulted in the acreage or wetlands our rules require, because the ratios are greater than 1:1, there has not been a net loss of wetland area. In fact, the two studies above found that, overall, wetland mitigation is resulting in 1.17 acre of wetland constructed for every acre of wetland lost. This study focused on evaluating the ecological condition of Ohio mitigation wetlands to determine if wetlands of equivalent quality were being created or restored.

Ohio Admininstrative Code (OAC) 3745-1-54(B) states that wetlands will be assigned to one of three categories "based on the wetland's relative functions and values, sensitivity to disturbance, rarity, and potential to be adequately compensated for by wetland mitigation." OAC 3745-1-54(C) states that wetlands assigned to category 1 support minimal ecological sevices and functions and are of poor quality, wetlands assigned to category 2 perform ecological services and functions at a moderate level and are of fair to good ecological condition and wetlands assigned to category 3 provide ecological services and functions at a superior level and demonstrate excellent ecological condition. OAC 3745-1-54(D) goes on to state that a category 1 wetland will be "replaced by a category 2 or category 3 wetland…" and a category 2 or a category 3 wetland will be replaced by a "wetland of equal or higher quality".

Many studies of mitigation wetlands have reported that for various reasons they provide a reduced level of functions and services and/or have a lower ecological condition than natural wetlands of the same type or class (NRC 2001, Robb 2002, Johnson et. al 2002, Porej 2003, Fennessy et. al 2004, Kettlewell 2005, Mack and Micacchion 2006, Kihslinger 2008). The goal of this study was to examine the condition of wetlands constructed to compensate for natural wetland losses authorized by permits as part of Ohio's wetland regulatory program. While replacement of adequate acreage was a concern we were most interested in knowing if wetland mitigation in Ohio is resulting in wetlands of equal or higher quality than those wetlands being lost.

Methods

Site Selection

The goal of this study was to evaluate a random sample of Ohio individual wetland mitigation projects to determine their overall ecological performance. Because, many more mitigation wetlands have been constructed in the decade after the Ohio Wetland Water Quality Standards were adopted (1998) than in the decade prior, a strictly random approach would be over represented by those mitigation wetlands established most recently. It is often believed that wetland mitigation construction that has been in existence for longer periods of time might be more mature and established and therefore might perform better.

To compensate for the potential of over representation bias as well as to incorporate the range of differing maturity levels, we stratified the population of wetland mitigation projects into three groups of age classes and randomly selected a like number of wetland projects from each. Mitigation wetlands were divided into the groups based on five year intervals. The resulting three groups are 0-5 years since construction (recent), 5-10 years since construction (middle), and greater than 10 years since construction (old). For each group eight wetland mitigation projects were selected, resulting in 24 sites, which was the maximum number of sites that could be monitored in a single field season given sampling resources and protocols.

A list of every Section 401 water quality certification and/or Isolated Wetland Permit that authorized wetland impacts and required wetland mitigation construction was generated. The list was then separated into the three groups based on the age of the project. Each wetland mitigation project was assigned a number. Then a random numbers program was used to select numbers for each group.

The files for the randomly selected projects were reviewed and if it could be documented that the project was constructed it was included in the study. If a project had not yet been constructed, the next random project was reviewed until eight projects from each time frame were chosen that actually had constructed wetlands on the ground. Three projects, one from the old group, and two from the middle group, had two separate locations for wetland mitigation construction. So for those two groups there were nine and ten wetlands monitored respectively. One wetland was dropped from the recent group because site visits revealed that, in fact, the wetland had never been constructed. We did not recognize the problem with the site until we had already started monitoring the wetlands. At that point it was too late to add an additional site. Therefore, for the recent group only seven wetlands were monitored and the total number of mitigation wetlands monitored for this study was 26 (Table 1).

Eleven locations had at least two, and in some cases as many as 12 wetlands, associated with the same wetland mitigation project. In these instances we selected the wetlands to monitor that, in our judgment, were demonstrating the highest levels of performance. In these situations, generally the same wetlands were monitored for the vegetation and amphibian assessments. However, in a couple of instances, to survey the highest performing conditions of both communities, separate wetlands were selected for the vegetation and amphibian evaluations.

Sampling methods - Level 1 Assessment

For each mitigation site included in this study, a digital boundary was created using "heads-up" digitizing techniques in ArcGIS 9.3.1 (Environmental Systems Research Institute, 1998-2009). Each of these mitigation site boundaries was buffered two different distances: 1) from the edge of the digital wetland polygon boundary to a distance of 100 meters ("inner zone"), and 2) from 100 to 350 meters away from the wetland boundary ("outer zone"). A Landscape Development Intensity (LDI) index was generated for each of these zones using 2001 National Land Cover Dataset (NLCD) data for Ohio (Brown and Vivas, 2005; Homer et. al., 2004). The LDI is a means of assigning a "human disturbance" value using land use data, allowing areas to be evaluated along a gradient of disturbance based on the LDI score. In this study, the number of raster cells falling within a wetland's inner or outer zone for each 1992 NLCD land use category was multiplied by the associated LDI coefficient, as listed on Table 2. The sum total of all LDI/land use calculations was then divided by the total number of raster cells associated with each inner and outer zone area.

All natural wetlands evaluated by the Ohio EPA Wetland Ecology Group were compared to the updated National Wetland Inventory (NWI) GIS layer generated for Ohio (National Wetlands Inventory, 2006-2007). A total of 197 natural wetlands clearly matched a digital polygon on the NWI layer and were therefore included in the study. These 197 NWI wetlands were buffered and an LDI calculation was conducted exactly as described previously for the mitigation wetlands.

Sampling methods - Level 3 Assessment

<u>Amphibians.</u> Funnel-ended activity traps were used for sampling the amphibians present in wetlands. Sample methods followed the amphibian IBI protocols in Micacchion (2004). Funnel traps were constructed of aluminum window screen cylinders with fiberglass window screen funnels at each end. Traps were 46 cm (18") in length, 20 cm (8") in diameter and each funnel end had 4.5 cm (1.75") openings. The funnel traps were similar in shape to commercially available minnow traps but with a smaller mesh-size. Ten funnel traps were placed evenly around the perimeter of each mitigation wetland and the trap location marked with flagging tape and numbered sequentially. Traps were set at the same locations throughout the sample period. Twenty-four of the 26 mitigation wetlands in the study were sampled for amphibians (Table 3). We monitored the

mitigation wetlands three times between March and July to fully capture the amphibian breeding season.

Traps were unbaited and left in the wetlands for 24 hours in order to ensure unbiased sampling for species with diurnal and nocturnal activity patterns. Upon retrieval, the traps were emptied by everting a funnel end and shaking the contents into a white collection and sorting pan. Individuals that could be readily identified in the field (typically adult amphibians) were recorded and released. The remaining amphibians were transferred to wide-mouth one liter plastic bottles and preserved with 95% ethanol. Laboratory identification of the preserved samples was carried out using the keys in Pfingsten and Downs (1989), Petranka (1998) and Walker (1946).

Vegetation. A plot-based vegetation sampling method was used to sample wetland plant communities (Peet et al., 1998). Sampling was performed in accordance with *Field Manual for the Vegetation Index of Biotic Integrity v. 1.4* (Mack 2007). At mitigation wetlands, a "standard" 20 m x 50 m plot was established (0.1 ha). The location of the plot was qualitatively selected by the investigators to capture the highest quality plant community present. Presence and areal cover was recorded for herb and shrub stratums; stem density and basal area was recorded for all woody species >1m. Percent cover was estimated using cover classes of Peet et al. (1998) (solitary/few, 0-1%, 1-2.5%, 2.5-5%, 5-10%, 10-25%, 25-50%, 50-75%, 75-90%, 90-95%, 95-99%). All woody stems >1 m tall were counted and placed into diameter classes (0-1 cm, 1- 2.5 cm, 2.5-5 cm, 5-10 cm, 10-15 cm, 20-25 cm, 25-30 cm, 30-35 cm, 35-40 cm) except that trees with diameters >40 cm were individually measured. The midpoints of the cover and diameter classes were used in all analyses. Other data collected included standing biomass (g/m^2 from eight $0.1m^2$ clip plots) and various physical variables (e.g. % open water, depth to saturated soils, amount of coarse woody debris, etc.). A soil pit was dug in the center of every plot and soil color, texture, and depth to saturation were recorded. A soil sample was taken at the center of the plot using an auger. A grab sample of water was also collected either at the time of the amphibian or vegetation sampling. The soil and water samples were analyzed for standard inorganic parameters at Ohio EPA's laboratory.

Data analysis

Minitab v. 15.0 was employed for the analyses of all data. Descriptive statistics, box and whisker plots, ANOVA, and regression analysis were used to evaluate the data.

Site Selection GIS Tool

A preliminary GIS application was created to aid in the selection of appropriate mitigation sites for Ohio. Data incorporated into this tool include:

1) A raster layer indicating all areas of Ohio that are composed of predominantly hydric soil (> 50% hydric inclusions) and have an agricultural land use classification. This layer was created by combining the NRCS Soil Survey Geographic Database (SSURGO) for Ohio (Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture, accessed 2009) with the 2001 NLCD (Homer et. al., 2004).

2) NWI wetlands identified as potential high quality vernal pools, and

3) Vernal pool restoration areas located within migration distance for pond-breeding amphibians which may be utilizing the existing potential high quality vernal pools.

A complete description of the GIS analysis used to create the two vernal pool layers is found in the Part 2 report for this grant (Gara and Micacchion, 2010). These layers are displayed on top of standard basemap data associated with typical Google map internet applications.

Results and discussion

Assessment of Condition of Mitigation Wetlands – Vegetation

A total of 26 wetland mitigation sites were monitored during the 2007 growing season using the Vegetation Index of Biotic Integrity (VIBI) protocols (Mack, 2007).

Based on the VIBI analysis of the mitigation wetlands monitored, two of the sites (Cambridge and Ethan's Green – 7.7%) did not have a predominance of hydrophytic vegetation and, therefore, did not meet the necessary criteria to be considered wetland habitat (Table 3). Of the remaining sites, eight (30.8%) were determined to be a Limited Quality Wetland Habitat ("poor"), eleven (42.3%) were Restorable Wetland Habitat ("fair"), and five (19.2%) were Wetland Habitat ("good") as defined by the proposed wetland tiered aquatic life uses (Mack, 2007) (Table 3). None of the mitigation wetlands included in this report scored as Superior Wetland Habitat ("excellent") using the VIBI field methodology.

The VIBI results for the mitigation sites were compared with past vegetation monitoring data on a subset of the Ohio EPA Wetland Ecology Group "reference wetland" dataset. A total of 197 natural wetlands were matched with a corresponding NWI polygon, as described in the methods section, and these represent the comparison wetlands included in the mitigation study. The mean VIBI score for all 26 mitigation wetlands is 34.35 which is significantly different than the mean VIBI score of 59.93 for the 197 natural wetlands included in the study ($df = 222$, $F = 26.78$, $p < 0.001$; Figure 2; Table 4). The natural wetland dataset was divided into three main vegetation classes (emergent, forested, and shrub), with a separate mean VIBI calculated for each. There was no significant difference between any of these natural wetland plant community VIBI scores (mean emergent VIBI = 61.38 [N=82], mean shrub VIBI = 62.24 [N=41], mean forested VIBI = 57.05 [N=74]) but all three differed significantly from the mean VIBI score of 34.35 calculated for the mitigation wetlands (Figure 3; Table 5).

The natural wetland data set was subdivided into their appropriate antidegredation category based on an ORAM version 5.0 analysis of each (Mack, 2001; Mack, 2001b), and then the mean VIBI scores for each category were compared with the mean VIBI score of all mitigation wetlands. As has been demonstrated in other studies conducted by the Ohio EPA Wetland Ecology Group (e.g., Mack and Micacchion 2006b, Fennessey et.al. 2007), the correlation between the ORAM rapid assessment tool and the more intensive level 3 VIBI analysis is very strong for this subset of natural wetlands in the Ohio EPA reference dataset (Figure 4). The mean VIBI scores for category 1 (mean VIBI = 20.95; N = 19) and modified category 2 (mean VIBI = 32.53; N = 17) natural wetlands did not differ significantly from one another. Both of these did differ significantly from the mean VIBI scores for category 2 (mean VIBI = 54.59; N = 54) and category 3 (mean VIBI = 73.86; N = 107) natural wetlands (Figure 5; Table 6). The mean VIBI score for mitigation wetlands (mean VIBI = 34.35, N = 26), however, only differed significantly from the mean VIBI scores for category 2 and category 3 wetlands. It appears that the plant communities developing in the mitigation sites included in this study corresponded most closely with modified category 2 wetlands in the natural wetland dataset. It is important to note, however, that only 5 of these mitigation wetlands (19.2%) fell into the “Wetland Habitat” (WLH) proposed wetland tiered aquatic life use. Most wetland mitigation creation and restoration projects authorized by Ohio EPA are required to meet, at a minimum, the threshold score for WLH (see Table 8, page15, in Mack and Micacchion 2006b) as a performance standard by the end of the prescribed monitoring period.

The natural wetland dataset was also broken down by LDI index score groups for both an “inner zone” (from wetland boundary to 100 meters) and “outer zone” (from 100 to 350 meters of wetland boundary), and the mean VIBI scores for each of these groups was compared to the mean VIBI score for the mitigation wetlands. The mean VIBI scores for two broad LDI groups in the inner zone (“High LDI” = 1.00 to 2.06, mean VIBI score = 65.64; “High LDI” = 2.06 to 7.06, mean VIBI score = 54.17) differed significantly from each other and both differed significantly from the mean VIBI score of 34.35 for mitigation wetlands (Figure 6; Table 7). An almost identical pattern emerged when the same comparison was made for natural wetlands VIBI scores which were grouped by High LDI (1:00 to 2.86) and Low LDI (2.86 to 8.00) scores in the outer zone (Figure 7; Table 8). Once again, the mean VIBI scores for the two natural wetland LDI breakdowns were significantly different from one another, and both differed significantly from the mean

VIBI score of 34.35 for mitigation wetlands. It appears that a clear relationship exists between the integrity of the inner and outer zones, as defined by the LDI index, surrounding natural wetland plant communities. The mean LDI score for the 26 mitigation wetlands in this study was 3.19 for the inner zone and 3.45 for the outer zone. These scores suggest that the high intensity land uses frequently occurring in the areas surrounding the mitigation wetlands may be contributing to the degraded plant communities associated with a majority of the sites evaluated.

This analysis was refined further by breaking the natural wetland dataset into 5 equal-sized groups based on the distribution of LDI scores for the inner and outer zones surrounding the wetlands. The mean VIBI scores for the first 4 inner zone LDI categories (LDI = 1:00 to 1.18, 1.18 to 1.76, 1.76 to 2.24, and 2.24 to 3.57) did not differ significantly from one another (Figure 8; Table 9). Each of these 4 groups did differ significantly with the mean VIBI score for the highest LDI group (LDI = 3.57 to 7.06) and also from the mean VIBI score of 34.35 for the 26 mitigation wetlands. There was no statistically significant difference between VIBI scores for the highest LDI natural wetland group and the mitigation wetlands. A very similar pattern was observed when the outer zone LDI scores were used to subdivide the natural wetland dataset (Figure 9; Table 10). As with the inner zone analysis, the mean VIBI scores for the four lowest LDI groups did not differ significantly from one another, but the lowest three groups were significantly different from the mean VIBI scores for the high LDI group and from the mitigation wetland mean VIBI. The mitigation VIBI score did not differ significantly from the high LDI natural wetland group. Rather than a linear relationship, this analysis suggests that there may be a “threshold” level of landscape disturbance within both the inner and outer zone areas surrounding wetlands, which is associated with a severe degradation of the plant community. The fact that both of zones, calculated independently, show virtually the same pattern with respect to the relationship between VIBI scores and LDI, strengthens the argument that there is a threshold level of disturbance that triggers a decline in the ecological integrity of the wetland plant community. Based on the preliminary data included in this study, this LDI threshold value appears to be about 3.00.

An LDI comparison was conducted using only the 26 mitigation wetlands included in this study. The sites were broken into low LDI and high LDI groups for both the inner zone (low LDI = 1.00 to 2.67, N=13; high LDI = 2.67 to 7.04; N=13) and outer zone (low LDI = 1.00 to 2.86, N=13; high LDI = 2.86 to 6.99; N=13) surrounding each wetland. Although the mean VIBI scores in both cases differed slightly from both of these zones, with the low LDI groups having slightly higher mean VIBI scores than the high LDI groups (**inner zone:** low LDI mean VIBI =37.08, high LDI mean VIBI = 31.62; **outer zone:** low LDI mean VIBI =37.92, high LDI mean VIBI = 30.77), neither of these differences was statistically significant (Figures 10, 11; Tables 11, 12).

An analysis of mitigation wetlands based on the proportion of the site that was considered to be "historic wetland" was conducted. The mitigation sites were divided into those that consisted of less than 10% historic wetland (mean VIBI score = 30.15; N = 13) and those that had greater than 10% of the area composed of historic wetland (mean VIBI score = 38.54). Although the sites having a greater proportion of historic wetland appeared to score slightly higher than those with little or no areas of historic wetland, this difference was not statistically significant (Figure 12, Table 13).

The mean VIBI scores for the mitigation wetlands were also compared to the approximate age classes used to classify the 26 wetlands as part of the site selection process. The mean VIBI scores for "old" (from 1991 to 1997; mean VIBI = 30.33; N = 9), "middle" (from 1998 to 2001; mean VIBI = 41.00; N=7), and "recent" (from 2002 to 2004; mean VIBI = 33.30; N = 10) did not differ significantly from one another (Figure 13, Table 14). While it is generally assumed that as a constructed wetland develops over time, the plant community should mature and the ecological integrity, as quantified by the VIBI score, should improve, this did not seem to be the case with this study.

Several factors appear to play a role in the potential success of a wetland mitigation site, including the presence of historic wetland soils, low levels of landscape disturbance in areas surrounding the wetland, appropriate hydrologic regime, and the planting of the site with an adequate diversity and density of native hydrophytic plant species. Poor site selection and/or construction in any one of these areas can result in a degraded plant community, as evidenced by several sites included in the study. While some of the mitigation wetlands appear to be achieving a VIBI score indicative of the "wetland habitat" tiered aquatic life use, the overall mean VIBI score for all mitigation sites (34.35) suggests that the ecological condition of these constructed wetlands is typically inferior to that of natural wetlands in Ohio.

Assessment of Condition of Mitigation Wetlands – Amphibians

Only those wetlands which held water continuously during the amphibian breeding season were monitored for amphibians. Therefore, 24 of the 26 mitigation wetlands in the study were monitored for amphibians. The amphibian communities encountered at the mitigation wetlands were predominately representative of low quality associations. Sixteen of the 24 wetlands monitored for amphibians had Amphibian Index of Biotic Integrity (AmphIBI) scores of 0 and another five had AmphIBI scores of six or less. Therefore, 21 of the wetlands had amphibian communities of poor quality (Limited Quality Wetland Habitat). Of the remaining three mitigation wetlands, one scored 13 and another 19, representing fair quality (Restorable Wetland Habitat), and the third was of excellent quality (Superior Wetland Habitat) having an AmphIBI score of 31. Overall, 87.5% (21) of the mitigation wetlands providing pond breeding amphibian habitat were of poor quality, 8.3% (2) were of fair quality and 4.2% (1) were of excellent quality.

Based on wetland categories, 21 of the 24 meet Category 1, two meet Category 2, and one meets Category 3 thresholds. For comparisons, our natural wetland dataset was divided into types based on whether they were predominantly forested and shrub, emergent or were urban (Micacchion and Gara 2008). Forested and shrub wetlands were further divided into categories based on breakpoints for ORAM scores and a separate mean AmphIBI was calculated for each (Table 16). There was a significant difference between the mean AmphIBI scores of Category 3 forested and shrub wetlands (mean AmphIBI = 33.88 [N=33]), Category 2 forested and shrub wetlands (mean AmphIBI = 23.81 [N=21]), and Category 1 forested and shrub wetlands (mean AmphIBI = 5.37 [N=6]). The mean AmphIBI scores for Category 2 and Category 3 natural forested and shrub wetlands were significantly different than those of mitigation wetlands (mean AmphIBI = 3.50 [N=24]), natural emergent wetlands (mean AmphIBI = 7.49 [N=41]) and natural urban wetlands (mean AmphIBI = 13.57 [N=14]). Mitigation mean AmphIBI scores were lower than any other wetland type. Based on these comparisons, it is readily apparent that the amphibian communities of the mitigation sites in this study were of lower quality than the communities associated with naturally-occurring Ohio wetlands of fair better ecological condition.

Figure 14 is a boxplot of AmphIBI scores by wetland type. On the left side of the graph are the natural forest and shrub wetlands divided into wetland categories based on ORAM scores. Natural emergent wetland AmphIBI scores are shown next, then the study wetlands, labeled “mitigation” and a set of urban wetlands occurs last. The boxplots show that the performance of these mitigation wetlands is not comparable to natural wetlands in “good” or better condition. With the exception of three mitigation wetlands (two fair and one excellent) all others scored in the poor range.

Ohio amphibians have been assigned coefficient of conservatism scores that allow them to be placed in groups based on their tolerance to human disturbances and the relative specificity of their habitat requirements (Micacchion et al. 2010, in prep.) Sensitive amphibian species were a rarity in mitigation wetlands and comprised only 1.8% (92) of the 4088 total amphibians collected. Tolerant amphibian species were by far the most numerous (3065) accounting for 75.0% of the individuals collected. Amphibian species with intermediate coefficient of conservatism scores made up the remaining 23.3% (951) of the individuals.

The Northern Green Frog, *Rana (Lithobates) clamitans melanota*, was by far the most abundant species comprising

48.1% of the 4088 amphibians collected. This pioneering species is extremely tolerant of pollution and can be found in a wide range of habitats, as long as they are wet enough to accommodate its needs, which is reflected in its assignment of the lowest coefficient of conservatism score of 1. Other abundant species were the Northern Leopard Frog, *Rana (Lithobates) pipiens* (22.7%) and Toads, *Bufo (Anaxyrus) sp.* (20.5%) (since toad tadpoles cannot be differentiated Eastern American Toad, *Bufo (Anaxyrus) americanus* and Fowler's Toad, *Bufo (Anaxyrus) fowleri* are combined as *Bufo (Anaxyrus) sp.*).

The other species collected during the study were Spring Peeper, *Pseudacris crucifer* (3.64%), American Bullfrog, *Rana (Lithobates) catesbeiana* (2.71%), Red-spotted Newt, *Notophthalmus viridescens* (0.86%), Wood Frog, *Rana (Lithobates) sylvatica* (0.83%), Western Chorus Frog, *Pseudacris triseriata* (0.27%), Gray Treefrog, *Hyla versicolor* (0.20%), Small-mouthed Salamander, *Ambystoma texanum* (0.10%), Jefferson Salamander, *Ambystoma jeffersonianum* (0.05%), and Northern Cricket Frog, *Acris crepitans* (0.02%). (Table 15).

The occurrence of Wood Frogs at the Columbia North mitigation site was notable and is the first time in our studies of individual wetland mitigation projects or wetland mitigation banks they have shown up in a collection. It also was the first time a monitored wetland mitigation site yielded AmphIBI scores equivalent to Superior Wetland Habitat (excellent), Category 3.

An examination of the age class of the wetlands as compared to their mean AmphIBI scores provided no statistically significant results (Table 17). However, mitigation wetlands in the "middle" age class scored higher on average than mitigation wetlands in either the "late" or "early" age class (Figure 15). Overall, the amount of time since the project had been constructed had no bearing on overall performance for amphibians.

Graphing of LDI scores against AmphIBI scores both at 100 meters and at 100 to 350 meters show no trends (Figures 16 and 17) and differences were not statistically significant (Tables 18 and 19). This is not surprising giving that most AmphIBI scores were uniformly low due to development of pools in areas far removed from existing high quality pond breeding amphibian habitat and their corresponding amphibian communities.

Assessment of Condition of Mitigation Wetlands – Wetland Hydrology

The percentage of the study mitigation wetlands that provided sufficient waters depths and duration to provide pond breeding amphibian habitat was much higher than what we have seen among groups of randomly selected natural wetlands and was a result of a larger percentage of mitigation wetlands having permanent hydrology. In our study of urban wetlands (Gamble et al. 2007) we found only 5 of 21 randomly selected natural

wetlands held water permanently. While only 23.8% of natural wetlands met this criterion a full 53.8% (14 of 26) of the randomly selected mitigation wetlands displayed permanent inundation. Since both populations were selected randomly this indicates that the mitigation wetlands on average were constructed to be on the wetter end of the wetland hydrological spectrum.
Owing to this design bias, mitigation wetlands had deeper water and retained water for a larger part of the year than their natural counterparts, and several of the mitigation wetlands were ponds rather than wetlands. These mitigation projects did not meet wetland criteria because vegetation was either completely absent or almost completely absent.

Hydrographs for each of the mitigation wetlands studied in this project appear in Figures 43 to 71. For comparison, hydrographs for natural depressional (Figures 72,73) and riverine wetlands (Figures 74,75) have also been included. When compared to the hydrographs of natural Ohio wetlands (Gamble et al 2007) the same trend of mitigation wetlands holding water for longer periods of time and with a larger percentage having permanent hydrology is seen. A natural hydrologic regime for most riverine and depressional wetlands in Ohio demonstrates a gradual reduction in water level late in the summer and into the fall. This seasonal drawdown is critical to the establishment and growth of many hydrophytic plant species. Longer hydroperiod durations have also been found to reduce overall species richness (Casanova and Brock, 1999). A majority of the mitigation wetlands studied in this project had continual water throughout the growing season, which undoubtedly influenced the species composition of the plant community and likely led to an overall reduction in average VIBI score. Future wetland mitigation projects need to place much greater emphasis on emulating a natural hydrologic regime in order to develop a diverse hydrophytic community. Without an improvement in the establishment of the appropriate hydrology, it is unlikely that many wetland restoration sites will be able to meet VIBI performance goals currently required for mitigation projects in Ohio.

Natural, appropriate hydroperiods are also of critical importance to pond-breeding amphibians. These organisms are adapted to seasonal hydrology. Their reproduction strategies, including the timing of their breeding events, are closely tied to the water levels and periods of inundation associated with the pools they utilize. The adults use environmental indicators (Sexton et al. 1990) to begin their breeding runs and rely on pools being filled when they reach them. Mating occurs and eggs are deposited shortly thereafter. For success, the pools must remain constantly inundated until the eggs have hatched, the larvae have developed and metamorphosed into young adults that can live in terrestrial environments away from the pools. This cycle varies in length, depending on the species, from two to four months or more. If the pools do not have water in them for sufficient duration, no recruitment can occur (Semlitsch 2000).

If inundation is permanent, however, some predatory fish (Hecnar and M'Closkey 1997) and invertebrate species (Colburn 2004) may become established. Most pond-breeding amphibians are not adapted to defend themselves against these aggressive predatory species. Under these conditions, successful reproduction is not possible, as both adults and larvae will be eliminated from the pools. The low AmphIBI scores recorded in many of the mitigation wetlands can be attributed, at least partially, to their permanent hydroperiods. The establishment of seasonal inundation is key to developing wetlands that provide the necessary habitat requirements for sensitive pond-breeding amphibian populations.

Overall Performance

To determine whether mitigation wetland projects had been successful we used a combination of VIBI and AmphIBI scores to provide the answer. Sites that had VIBI and/or AmphIBI scores that placed them in the upper tier of Category 2 (Wetland Habitat) or higher were considered to be successful. This is a performance standard used in Ohio for all individual wetland mitigation projects as well as wetland mitigation banks. Meeting scores equivalent to the Wetland Habitat range indicates that a wetland is performing at levels equivalent to natural wetlands of its type in "good" ecological condition, Scores in this range also indicate that, with proper management these wetlands should be able to maintain or improve on that condition over time and will continue to be successful.

Mitigation wetlands that met either VIBI and/or AmphIBI scores equivalent to the lower tier of Category 2 (Restorable Wetland Habitat), were constructed within five years (recent group) and therefore were still within their monitoring periods, were considered to be potentially successful. Meeting these wetland scores meant the mitigation wetlands were comparable to natural wetlands of their type that demonstrate "fair" ecological condition. While performance levels of these wetlands were less than "good" and below the prescribed performance standard, since it had been a relatively short period of time since their construction it was felt with more time they might improve.

Mitigation projects that had VIBI or AmphIBI scores equivalent to Category 1 and those with scores in the lower tier of Category 2 that had been constructed for more than five years were considered to be failures. These wetlands were equivalent to natural wetlands of their type that are of "poor" or "fair" ecological condition. We felt in order for any of these sites to have a chance at success would require, at a minimum, significant modifications to occur. Some were located on such problematic sites that the only way success could be achieved would be to start over at a new location.

Using these criteria, 23.08% (6 sites) of the mitigation wetlands monitored were successful, 15.38% (4 sites) were potentially successful, and 61.54% (16 sites) were failures. The good news is that close to a fourth of the sites were successful and another four sites had the potential to be successful with more time. Unfortunately, based on Ohio's performance standards, well over half were failures. Given the state of the science on wetland restoration it was hoped that the success rate would be much higher.

It is our belief that the knowledge to develop good sites is available but is not being used often enough to make informed decisions about incorporating the best project locations, designs, construction methods and management. Those projects that were successful put most of the concepts necessary for restoration of high quality wetlands into play and that is reflected in the results.

Factors Affecting Performance

The reasons for under performance have been many. First on the list is the selection of sites for wetland development that are not optimal. When less than ideal sites are selected, manipulations of existing landscape features are necessary and they can often be large-scale. These manipulations result in a disturbed landscape and unnatural conditions that are often not conducive to the establishment of quality wetlands.

True restorations are the best candidates for success. These projects are the ones undertaken on areas were wetlands previously existed. Hydric soil areas provide accurate information on where wetlands once resided and should be targeted with the emphasis on returning the original hydrology to the site. Once appropriate soils and hydroperiods are present wetland plant communities can become established. Plant establishment should occur through a combination of seeding and planting. Planting of woody species is required if the target is a forested or shrub wetland. These seedings and plantings need to occur at high densities with the goal of completely covering the wetland footprints with a carpet of plant material. Relying on the seedbank alone is not sufficient and will generally yield a very tolerant, and sometimes sparse, plant community. A lack of density of vegetative cover provides opportunities for establishment of tolerant and invasive plant species.

Some soil series can be defined as totally hydric and are ideal for restorations. However, often non-hydric soil series that have areas of hydric soil inclusions are selected as sites for wetland mitigation. All planned wetlands should be limited to the extent of the hydric soil footprints on the project site. This means that some type of delineation of hydric soils on the project area needs to occur and the hydric soil areas mapped. Ideally, any modifications should involve as little disturbance as possible to the project landscape and generally should only require minimal manipulations. These might involve such activities as a perimeter tile search with corresponding tile decommissioning or elimination of previously developed artificial drainage ways through filling, plugging or impoundment.

Also, addition of hydrology to natural wetlands is most often not an enhancement. When wetlands are underperforming due to a lack of hydrology it is a fine line and difficult task, needing constant monitoring, to add just enough water to provide benefits and not so much that it is detrimental. If the wetlands are already performing at a reasonable level, adding more water is not advisable. It will drown out some of the establish plants, most often the woody species, and result in unvegetated areas. The unvegetated areas may remain without plants, especially if water depths are significant, may develop into a lower quality plant community than what existed or may allow the establishment of invasive species. It is rare that adding hydrology to an existing wetland results in an improved ecological condition.

Another prime factor in underperforming wetland mitigation projects is disturbance of natural soil profiles. Once soils have been excavated, re-contoured and compacted by heavy equipment the growing median necessary for successful plant growth is lost or greatly impaired. Many years must pass before the natural soil profile and topsoil nutrient levels are restored. Some success has been attributed to stockpiling hydric topsoils and then redistributing a top layer, of a few to several inches, once excavation and other grading is completed. However, the best practice is to leave the soil intact when and where possible. Where grading is required because wetland topographic features have been eliminated through past land use practices, the amount of soil disturbance should be limited to the bare minimum. In some of these instances low berms, rather than grading or excavation, to inundate and saturate hydric soils may be a more ecologically friendly alternative.

Development of unnatural, permanent hydroperiods along with development of steep slopes and deep water areas resulting in pond-like conditions is another common design flaw of many wetland mitigation projects. Several of the projects in this study demonstrated these characteristics and had extremely depauperate plant communities. A couple of these also had large areas of unvegetated open water and one had no plants at all. As well as being poor from an ecological perspective, these areas do not meet wetland criteria (Environmental Laboratory 1987) and were unsuccessful on that basis. These projects had the additional hurdles of having been largely excavated and/or had their basin established through extensive berm and dike development. Therefore, much disturbance of the local landscapes had occurred and the natural soil profiles had been lost. Plant growth cannot be expected to be robust on nutrient poor, compacted soil under a couple to several feet of turbid water.

While site selection is the top priority in developing a successful wetland mitigation project, aggressive and proactive management is essential at even the best located, designed and constructed sites.

Based on site selection and project planning, some of the projects in this study were doomed from the beginning. However, many of the successes and failures could be attributed to the level of management or non-management the sites received. Probably the management practice most often neglected was immediate and complete treatment of invasive plant species. Once these invaders become established it is an uphill battle to remove them and only rigorous and repetitive treatment, that is labor and resource intensive, will provide any chance of elimination. Where management was applied as invasive plant species appeared the number of plants needed to be dealt with remained small and eradication was possible.

Another aspect often neglected in these projects was management and adjustment of water levels to maximize the ecological condition of the wetlands. A couple of projects held water for much shorter periods of time then natural wetlands of their hydrogeomorphic class. This underachievement was likely due to active tiles or some other drainage feature having not been rendered useless during the construction process resulting in less than the planned hydroperiod. However, no follow-up attempts had been made to try to find and remedy to these situations in those cases. With a little longer time of inundation and saturation both of these mitigation projects would have been higher performing.

A good number of the wetlands had the opposite problem of holding water at depths and durations that were unnatural for wetlands as well as being detrimental to their quality. These projects resulted in water bodies that had many more pond-like rather than wetland features. Those characteristics included steep side slopes resulting in bowl shapes with deep water zones having little or no vegetation. While some improvements were possible through water management the problems were mostly design flaws than could not be easily overcome. However, no evidence of any attempt existed, for any of the projects demonstrating these flaws, of trying to establish a more natural and higher quality wetland by decreasing the depths and lengths of inundation through available means or by modifying the constructed water holding structures.

Another large problem was the condition of the areas surrounding the wetland pools. There was a distinct tendency to keep areas adjacent to the mitigation wetlands in too intensive of land uses to expect the wetlands to be of high quality. Especially for the failures, any buffering from the surrounding land uses was rare. Of study wetlands that had buffers, none demonstrated any active reforestation or other measures to improve buffer quality. Where buffers were not actively maintained, natural succession was the only mechanism for improvement of the vegetation communities. Many of the study wetlands had areas of actively mowed grass in contact with some, or all, of their perimeter. Others had parking lots, golf courses, roads, railroads, landfills and ponds either in contact with their borders or short distances away. These conditions add to the understanding of the overall low level of performance of many of the study wetlands.

Wetland Mitigation Site Selection Google Maps Application

Site selection is clearly an important consideration when developing appropriate wetland mitigation. As a part of this project, we have developed an preliminary Google Map application to aid in the identification of potential wetland restoration sites, with an emphasis on vernal pool habitat. This application can be accessed from the following location:

http://wwwapp.epa.ohio.gov/dsw/gis/vernal/

It is important to note that Ohio EPA makes no claims regarding the accuracy of this information. This application is intended to be used for planning purposes only. Any sites targeted for wetland re-establishment would need to be investigated thoroughly in the field to verify their restoration potential.

Conclusions

Our study of 26 randomly selected mitigation wetlands provided insights on the state of wetland replacement in Ohio and the reasons for successes and failures. It was disappointing that well over half (16 sites, 61.54%) of the projects resulted in failures and another 15.38% (4 sites) have not yet met performance standards. These results point out the assumption that impacted wetlands can be replaced has been wrong for a great percentage of permitted wetland impacts. The large percentage of failure also illustrates a need for a major overhaul in how wetland mitigation projects are reviewed and implemented if we are to be successful in regulating wetland impacts. The bar needs to be raised on what is an acceptable wetland mitigation proposal. This should include more rigorous review of mitigation plans along with field verification of site conditions along with later field follow up to assure the projects are being implemented and managed as planned. Most importantly, the results strongly indicate added protections should be provided to moderate and higher quality wetlands, as it is rare that these aquatic resources which are adequately replaced through wetland mitigation.

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Table 1. Mitigation sites included in study.

Site Name	Applicant Name	County	Ecoregion	Plant Community	HGM Class	Year	Age Group
Admore Drive	City of Kent	Portage	Erie-Ontario Drift and Lake Plains	Mixed Emergent Marsh	Human Impoundment	2002	Recent
BFI	Browning Ferris Industries of Ohio	Lorain	Erie-Ontario Drift and Lake Plains	Mixed Emergent Marsh	Surface Depression	2003	Recent
Bazetta	Bazetta Township Trustees	Trumbull	Erie-Ontario Drift and Lake Plains	Mixed Emergent Marsh	Human Impoundment	1996	Old
Brookside Park	Duke Construction	Cuyahoga	Erie-Ontario Drift and Lake Plains	Cattail Marsh	Human Impoundment	1999	Middle
Cambridge	City of Cambridge	Guernsey	Western Allegheny Plateau	None	Mainstem Depression	1991	Old
Chip Hess	Duke Construction	Geauga	Erie-Ontario Drift and Lake Plains	Mixed Emergent Marsh	Human Impoundment	1999	Middle
Columbia North Marsh	Department of Port Control	Lorain	Erie-Ontario Drift and Lake Plains	Mixed Emergent Marsh	Human Impoundment	2001	Middle
Conrail	Consolidated Rail Corporation	Logan	Eastern Corn Belt Plains	Sedge-Grass Meadow	Surface Depression	1998	Middle
Danis	Danis Clarkco Landfill Company	Clark	Eastern Corn Belt Plains	Mixed Emergent Marsh	Human Impoundment	1995	Old
Ethan's Green	Sunrise Land Company	Summit	Erie-Ontario Drift and Lake Plains	None	Human Impoundment	1993	Old
Flying J	Flying J Inc.	Trumbull	Erie-Ontario Drift and Lake Plains	Sedge-Grass Meadow	Surface Depression	2002	Recent
Girdled Road	Milton A. Wolf Investors	Lake	Erie-Ontario Drift and Lake Plains	Mixed Emergent Marsh	Surface Depression	2001	Middle
Golden Links	Debartolo Corporation	Summit	Erie-Ontario Drift and Lake Plains	Swamp Forest	Human Impoundment	2000	Middle
Indian Hollow	Department of Port Control	Lorain	Erie-Ontario Drift and Lake Plains	Sedge-Grass Meadow/Mixed Emergent Marsh	Surface Depression	2001	Middle
Mantua Center	Parma Land Development, LLC	Portage	Erie-Ontario Drift and Lake Plains	Mixed Emergent Marsh	Human Impoundment	2001	Middle
Medallion	Champions Development Group	Delaware	Eastern Corn Belt Plains	Mixed Emergent Marsh	Surface Depression	1992	Old
Mud Bog	City of Hudson	Summit	Erie-Ontario Drift and Lake Plains	Sedge-Grass Meadow	Mainstem Depression	2000	Middle
Penney	Defiance County Landfill Expansion	Defiance	Huron-Erie Lake Plains	Mixed Emergent Marsh	Human Impoundment	2004	Recent
R&F Coal	R&F Coal Company	Belmont	Western Allegheny Plateau	Submergent Marsh	Human Impoundment	1992	Old
Rapids Road	Geauga County Engineers	Geauga	Erie-Ontario Drift and Lake Plains	Cattail Marsh	Mainstem Depression	1997	Old
Rolling Hills	PFR Land Company	Summit	Erie-Ontario Drift and Lake Plains	Mixed Emergent Marsh	Human Impoundment	2003	Recent
Sippo Lake Marsh	Stark County Park District	Stark	Erie-Ontario Drift and Lake Plains	Mixed Emergent Marsh	Human Impoundment	1995	Old
Sippo Lake Meadow	Stark County Park District	Stark	Erie-Ontario Drift and Lake Plains	Sedge-Grass Meadow	Isolated Slope	1995	Old
Sydney's Bend	Sydney’s Bend, LLC	Montgomery	Eastern Corn Belt Plains	Mixed Emergent Marsh	Headwater Depression	2004	Recent
Wal-Mart	Wal-Mart Stores Inc., Boardman, OH	Mahoning	Erie-Ontario Drift and Lake Plains	Mixed Emergent Marsh	Human Impoundment	2003	Recent
Willow Point	Ohio Department of Transportation	Erie	Huron-Erie Lake Plains	Submergent Marsh	Diked-Managed Coastal	2001	Middle

Table 2. 2001 National Land Cover Dataset (NLCD) Land Use Categories and corresponding Landscape Development Intensity (LDI) Coefficients (*derived from* Brown and Vivas, 2005).

Land Use Category	LDI Coefficient
11 (Open Water)	1.00
21 (Developed, Open Space)	6.92
22 (Developed, Low Intensity)	7.47
23 (Developed, Medium Intensity)	7.55
24 (Developed, High Intensity)	9.42
31 (Barren Land)	8.32
41 (Deciduous Forest)	1.00
42 (Evergreen Forest)	1.00
43 (Mixed Forest)	1.00
52 (Shrub/Scrub)	2.02
71 (Grassland/Herbaceous)	3.41
81 (Pasture/Hay)	3.74
82 (Cultivated Crops)	4.54
90 (Woody Wetlands)	1.00
95 (Emergent Herbaceous Wetlands)	1.00

Table 3. Mitigation sites with VIBI score, VIBI Wetland Tiered Aquatic Life Uses (TALUs), AmphIBI score, AmphIBI TALUs, Landscape Development Intensity (LDI) scores (inner and outer zone), and Estimated %Historic Wetland. Wetland TALU categories are as follows: Limited Quality Wetland Habitat (LQWLH), Restorable Wetland Habitat (RWLH), Wetland Habitat (WLH), and Superior Wetland Habitat (SWLH).

Site Name	VIBI Score	VIBI TALUs	AmphIBI Score	AmphIBI TALUs	"Inner Zone" LDI (0 to 100 meters)	"Outer Zone" LDI (100 to 350 meters)	Historic Wetland%
Admore Drive	30	RWLH	0	LQWLH	4.53	5.14	100.00
BFI	56	RWLH	0	LQWLH	3.58	4.80	57.51
Bazetta	59	WLH	0	LQWLH	1.00	2.20	7.88
Brookside Park	29	RWLH	0	LQWLH	2.63	6.25	3.61
Cambridge	+0	LQWLH	0	LQWLH	2.71	3.84	7.25
Chip Hess	56	WLH	0	LQWLH	2.09	2.35	46.67
Columbia North Marsh	30	RWLH	31	SWLH	*2.67	*2.86	*2.36
Conrail	16	LQWLH	19	RWLH	**4.88	**4.24	**36.93
Danis	37	RWLH	0	LQWLH	2.44	2.72	0.00
Ethan's Green	+0	LQWLH	0	LQWLH	6.86	5.98	0.00
Flying J	57	RWLH	0	LQWLH	2.45	3.56	1.86
Girdled Road	43	RWLH	6	LQWLH	1.93	1.44	0.00
Golden Links	0	LQWLH	6	LQWLH	1.60	2.81	90.00
Indian Hollow	70	WLH	N/A	N/A	3.09	2.44	15.00
Mantua Center	42	RWLH	3	LQWLH	3.87	3.22	100.00
Medallion	26	RWLH	0	LQWLH	7.04	6.99	5.00
Mud Bog	27	LQWLH	0	LQWLH	3.18	2.81	88.88
Penney	23	LQWLH	3	LQWLH	3.81	3.00	3.00
R&F Coal	23	LQWLH	0	LQWLH	1.09	1.24	5.00
Rapids Road	22	LQWLH	0	LQWLH	1.99	1.62	80.79
Rolling Hills	26	LQWLH	0	LQWLH	5.15	4.67	4.32
Sippo Lake Marsh	43	RWLH	0	LQWLH	1.05	2.22	62.16
Sippo Lake Meadow	63	WLH	N/A	N/A	1.00	2.63	72.02
Sydney's Bend	39	RWLH	13	RWLH	6.64	5.30	5.00
Wal-Mart	56	WLH	0	LQWLH	4.70	3.18	100.00
Willow Point	20	LQWLH	3	LQWLH	1.00	2.15	37.30

+ Not meeting wetland criteria (no predominance of hydrophytic vegetation).

* AmphIBI and VIBI results from 2 separate wetland cells. For AmpbIBI cell, Inner Zone LDI = 1.09, Outer Zone LDI = 1.89, and Percent Historic Wetland = 0.00%.

** AmphIBI and VIBI results from 2 separate wetland cells. For AmpbIBI cell, Inner Zone LDI = 4.20, Outer Zone LDI = 4.58, and Percent Historic Wetland = 54.77%.

Table 4. Comparison of mean (standard deviation) VIBI scores for natural wetlands with VIBI scores for mitigation wetlands. Means without shared letters are significantly different (p <0.05) after Tukey's multiple comparison test.

Wetland Type	N	VIBI Score
Natural	197	59.93 (24.17) A
Mitigation	26	34.35 (19.60) B
df		222
F		26.78
p value		0.000

Table 5. Comparison of mean (standard deviation) VIBI scores for natural wetlands (by major plant community type) with VIBI scores for mitigation wetlands. Means without shared letters are significantly different (p <0.05) after Tukey's multiple comparison test.

Wetland Type	N	VIBI Score
Natural Emergent	82	61.36 (25.28) A
Natural Shrub	41	62.24 (23.76) A
Natural Forested	74	57.05 (23.16) A
Mitigation	26	34.35 (19.60) B
df		222
F		9.51
p value		0.000

Table 6. Comparison of mean (standard deviation) VIBI scores for natural wetlands (by ORAM antidegredation category) with VIBI scores for mitigation wetlands. Means without shared letters are significantly different ($p < 0.05$) after Tukey's multiple comparison test.

Wetland Type	N	VIBI Score
Natural – Category 1	19	20.95 (20.10) A
Natural – Modified Category 2	17	32.53 (15.35) A
Natural – Category 2	54	54.69 (15.78) B
Natural – Category 3	107	73.86 (15.77) C
Mitigation	26	34.35 (19.60) A
df		222
F		71.43
p value		0.000

Table 7. Comparison of mean (standard deviation) VIBI scores for natural wetlands (Low LDI and High LDI groups for area within 0 to 100 meters of wetland boundary) with VIBI scores for mitigation wetlands. Means without shared letters are significantly different (p <0.05) after Tukey's multiple comparison test.

Wetland Type	N	VIBI Score
Natural – Low LDI (1.00 – 2.06)	99	65.64 (20.95) A
Natural – High LDI (2.06 – 7.06)	98	54.17 (25.89) B
Mitigation	26	34.35 (19.60) C
df		222
F		20.11
p value		0.000

Table 8. Comparison of mean (standard deviation) VIBI scores for natural wetlands (Low LDI and High LDI groups for area from 100 to 350 meters of wetland boundary) with VIBI scores for mitigation wetlands. Means without shared letters are significantly different ($p < 0.05$) after Tukey's multiple comparison test.

Wetland Type	N	VIBI Score
Natural – Low LDI (1.00 – 2.86)	99	67.40 (21.36) A
Natural – High LDI (2.06 – 8.00)	98	52.39 (24.59) B
Mitigation	26	34.35 (19.60) C
df		222
F		25.45
p value		0.000

Table 9. Comparison of mean (standard deviation) VIBI scores for natural wetlands (5 equal LDI groups for area within 0 to 100 meters of wetland boundary) with VIBI scores for mitigation wetlands. Means without shared letters are significantly different ($p < 0.05$) after Tukey's multiple comparison test.

Wetland Type	N	VIBI Score
Natural: LDI 1.00 – 1.18 (Mean LDI = 1.05)	40	66.48 (20.37) A
Natural: LDI 1.18 – 1.76 (Mean LDI = 1.46)	39	63.62 (21.76) A
Natural: LDI 1.76 – 2.24 (Mean LDI = 2.01)	40	67.23 (22.71) A
Natural: LDI 2.24 – 3.57 (Mean LDI = 2.87)	39	62.46 (20.83) A
Natural: LDI 3.57 – 7.06 (Mean LDI = 4.73)	39	39.54 (24.53) B
Mitigation: LDI 1.00 – 7.04 (Mean LDI = 3.19)	26	34.35 (19.60) B
df		222
F		15.08
p value		0.000

Table 10. Comparison of mean (standard deviation) VIBI scores for natural wetlands (5 equal LDI groups for area from 100 to 350 meters of wetland boundary) with VIBI scores for mitigation wetlands. Means without shared letters are significantly different ($p < 0.05$) after Tukey's multiple comparison test.

Wetland Type	N	VIBI Score
Natural: LDI 1.00 – 1.60 (Mean LDI = 1.37)	41	68.02 (21.98) A
Natural: LDI 1.60 – 2.53 (Mean LDI = 2.11)	39	67.56 (18.94) A
Natural: LDI 2.53 – 3.23 (Mean LDI = 2.88)	39	64.21 (23.52) A
Natural: LDI 3.23 – 4.56 (Mean LDI = 3.88)	39	55.49 (27.15) A, B
Natural: LDI 4.56 – 8.00 (Mean LDI = 5.63)	39	43.97 (20.60) B, C
Mitigation: LDI 1.24 – 6.99 (Mean LDI = 3.45)	26	34.35 (19.60) C
df		222
F		12.65
p value		0.000

Table 11. Comparison of mean (standard deviation) VIBI scores for mitigation wetlands broken down by Low LDI and High LDI groups for area within 0 to 100 meters of wetland boundary. Means without shared letters are significantly different (p <0.05) after Tukey's multiple comparison test.

Wetland Type	N	VIBI Score
Mitigation Wetlands: LDI 1.00 to 2.67 (Mean LDI = 1.76)	13	37.08 (18.67) A
Mitigation Wetlands: LDI 2.68 to 7.04 (Mean LDI = 4.62)	13	31.62 (20.87) A
Df		25
F		0.49
p value		0.489

Table 12. Comparison of mean (standard deviation) VIBI scores for mitigation wetlands broken down by Low LDI and High LDI groups for area from 100 to 350 meters of wetland boundary. Means without shared letters are significantly different ($p < 0.05$) after Tukey's multiple comparison test.

Wetland Type	N	VIBI Score
Mitigation Wetlands: LDI 1.24 to 2.86 (Mean LDI = 2.27)	13	37.92 (20.21) A
Mitigation Wetlands: LDI 2.87 to 6.99 (Mean LDI = 4.63)	13	30.77 (19.10) A
Df		25
F		0.86
p value		0.363

Table 13. Comparison of mean (standard deviation) VIBI scores for mitigation wetlands broken down by estimated percent historic wetland. Means without shared letters are significantly different ($p < 0.05$) after Tukey's multiple comparison test.

Wetland Type	N	VIBI Score
Mitigation Wetlands: Historic Wetland < 10%	13	30.15 (17.79) A
Mitigation Wetlands: Historic Wetland > 10%	13	38.54 (21.12) A
Df		25
F		1.20
p value		0.284

Table 14. Comparison of mean (standard deviation) VIBI scores for mitigation wetlands for three age classes. Means without shared letters are significantly different ($p < 0.05$) after Tukey's multiple comparison test.

Wetland Type	N	VIBI Score
Mitigation Wetlands: Age Class = “Old” (1991 - 1997)	9	30.33 (22.57) A
Mitigation Wetlands: Age Class = “Middle” (1998 - 2001)	7	41.00 (15.17) A
Mitigation Wetlands : Age Class = “Recent” (2001 - 2004)	10	33.30 (20.24) A
Df		25
F		0.59
p value		0.565

Table 15. Amphibian species collected, relative abundances and AmphIBI scores for mitigation wetlands.

Site	AMBJEF	AMBTEX	NOTVIR	ACRCRE	BUFOSP	HYLVER	PSECRU	PSETRI	RANCAT	RANCLA	RANPIP	RANSYL	# of IND.	AmphIBI Score
ADMORE					2	3			2	175	6		188	0
BAZETTA						5	7		10	115			137	0
BFI										3			3	0
BROOKSIDE PARK									2	21	2		25	0
CAMBRIDGE									1				1	0
CHIP HESS										9			9	0
COLUMBIA							18			10	27	34	89	31
CONRAIL		4	1		67		3	11			348		434	19
DANIS									1				1	0
ETHAN'S GREEN									6	8			14	0
FLYING J							12			312			324	0
GIRDLED ROAD	2		33		766					64			865	6
GOLDEN LINKS			1						4	413	7		425	6
MANTUA CENTER							103				7		110	3
MEDALLION									1	542			543	0
MUD BOG					3					2			5	0
PENNEY				1	1				1	35			38	3
R&F COAL										17			17	0
RAPIDS ROAD										131			131	0
ROLLING HILLS										1			1	0
SIPPO LAKE							4		81	104			189	0
SYDNEY'S BEND											526		526	13
WAL MART							2		1				3	0
WILLOW POINT									1	4	5		10	3
Totals	2	4	35	1	839	8	149	11	111	1966	928	34	4088	
Relative Abundance	0.00049	0.00098	0.00856	0.00024	0.20523	0.00196	0.03645	0.00269	0.02715	0.48092	0.22701	0.00832	1.00000	

Table 16. Comparison of mean (standard deviation) AmphIBI scores for natural shrub and forested (by ORAM antidegredation category), natural emergent, natural urban, mitigation bank and mitigation wetlands. Means without shared letters are significantly different ($p < 0.05$) after Tukey's multiple comparison test.

Wetland Type	N	AmphIBI Score
Natural SS & F – Cat. 1	6	5.67 (5.54) C
Natural SS & F – Cat. 2	21	23.81 (16.08) A
Natural SS & F– Cat. 3	33	35.88 (13.33) B
Natural - Emergent	41	7.48 (9.70) C
Natural - Urban	14	13.57 (6.57) C
Mitigation Bank	35	0.343 (0.97) C
Mitigation	24	3.50 (7.51) C
df		183
F		46.23
p value		0.000

Table 17. Comparison of mean (standard deviation) AmphIBI scores for mitigation wetlands for three age classes. Means without shared letters are significantly different (p <0.05) after Tukey's multiple comparison test.

Wetland Type	N	AmphIBI Score
Mitigation Wetlands: Age Class = "Old" (1991 - 1997)	8	0.000 (0.000) A
Mitigation Wetlands: Age Class = "Middle" (1998 - 2001)	9	7.556 (10.596) A
Mitigation Wetlands : Age Class = "Recent" (2001 - 2004)	7	2.286 (4.855) A
Df		23
F		2.59
p value		0.099

Table 18. Comparison of mean (standard deviation) AmphIBI scores for mitigation wetlands broken down by Low LDI and High LDI groups for area within 0 to 100 meters of wetland boundary. Means without shared letters are significantly different ($p < 0.05$) after Tukey's multiple comparison test.

Wetland Type	N	AmphIBI Score
Mitigation Wetlands: LDI 1.00 to 2.67 (Mean LDI = 1.77)	14	5.357 (9.378) A
Mitigation Wetlands: LDI 2.68 to 7.04 (Mean LDI = 4.37)	10	0.900 (2.025) A
Df		23
F		2.16
p value		0.156

Table 19. Comparison of mean (standard deviation) VIBI scores for mitigation wetlands broken down by Low LDI and High LDI groups for area from 100 to 350 meters of wetland boundary. Means without shared letters are significantly different ($p < 0.05$) after Tukey's multiple comparison test.

Wetland Type	N	AmphIBI Score
Mitigation Wetlands: LDI 1.24 to 2.86 (Mean LDI = 2.22)	13	2.923 (6.034) A
Mitigation Wetlands: LDI 2.87 to 6.99 (Mean LDI = 4.63)	11	4.182 (9.218) A
Df		23
F		0.16
p value		0.692

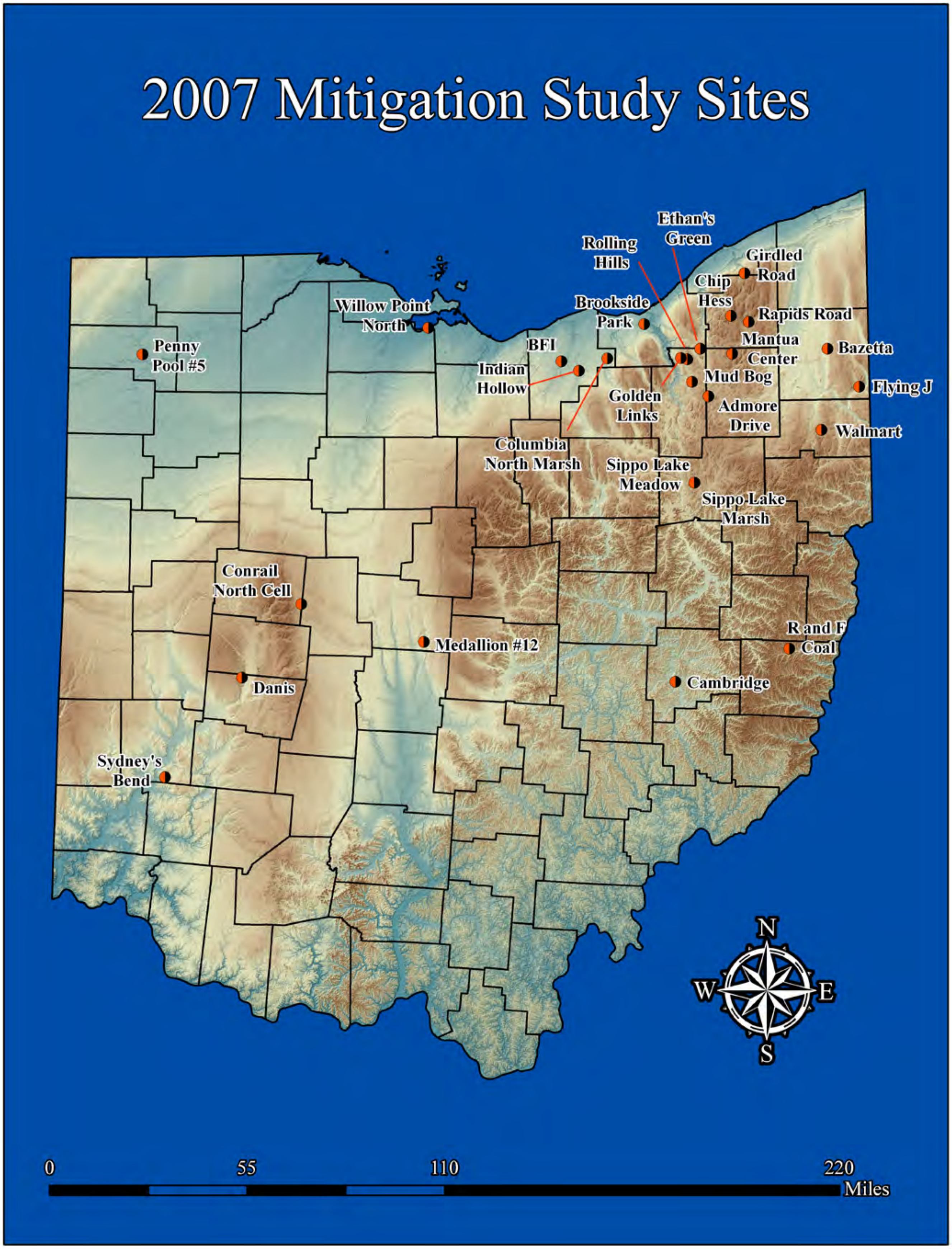

Figure 1. Locations of all Ohio sites included in the 2007 mitigation study.

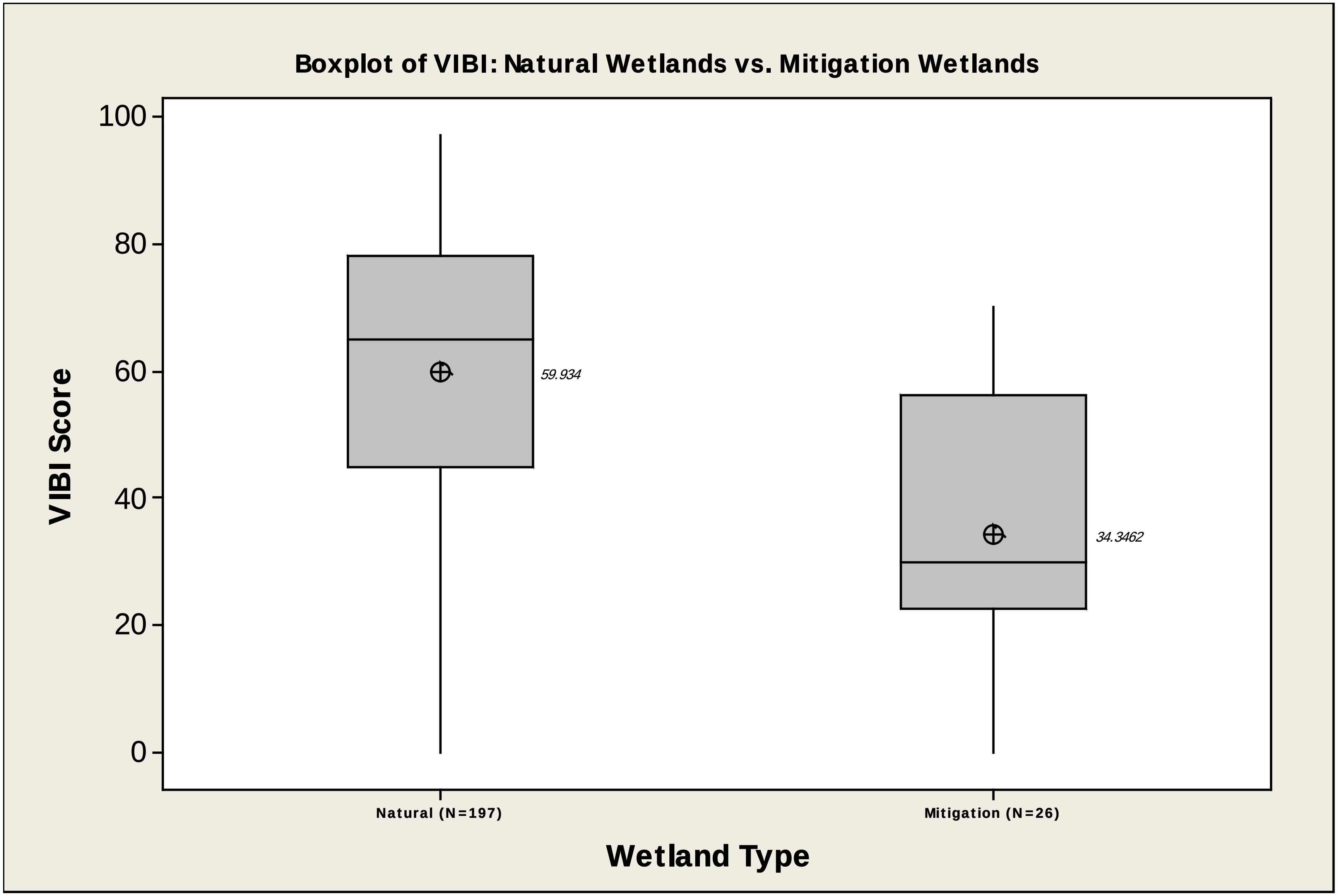

Figure 2. Box and whiskers plot comparing mean VIBI score for natural wetlands with mean VIBI score for mitigation wetlands (df = 222, F = 26.78, $p < 0.001$).

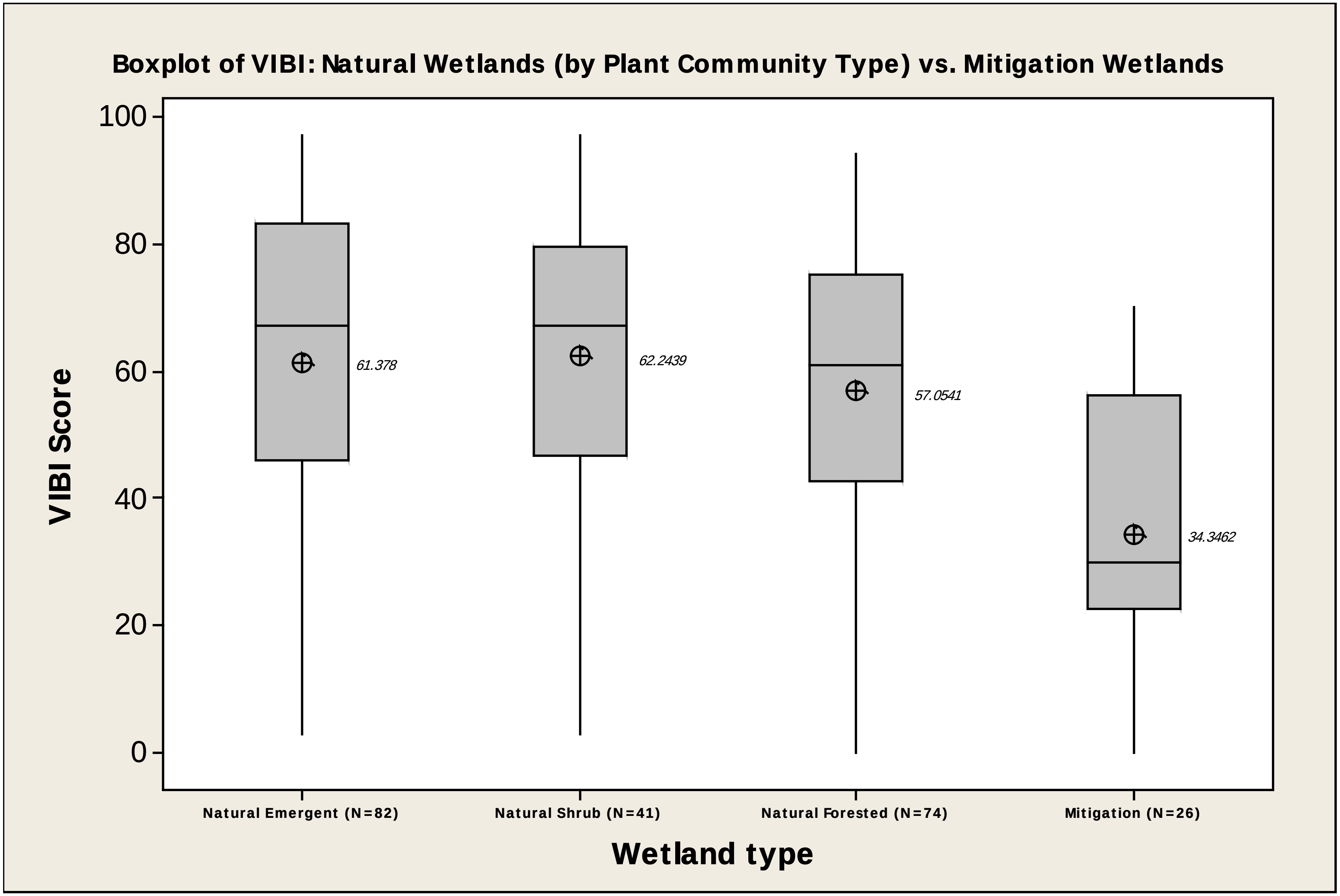

Figure 3. Box and whiskers plot comparing mean VIBI score for natural wetlands (by plant community type) with VIBI scores for mitigation wetlands (df = 222, F = 9.51, $p < 0.001$).

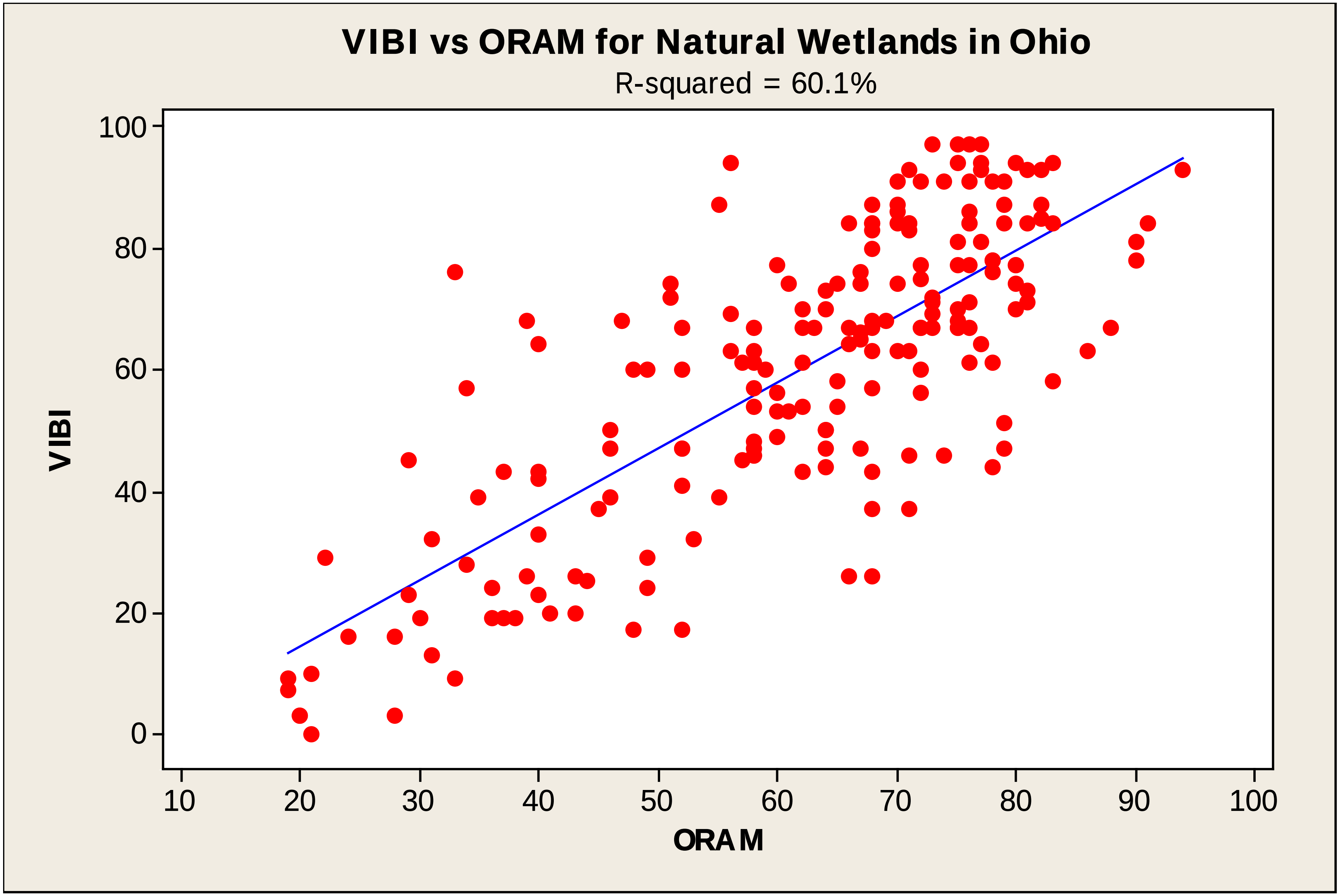

Figure 4. Fitted line regression plot of VIBI vs. ORAM scores for natural wetlands in the Ohio EPA reference wetland dataset with a corresponding NWI polygon (df = 196, F = 294.3, p = 0.000, R-squared = 60.1%).

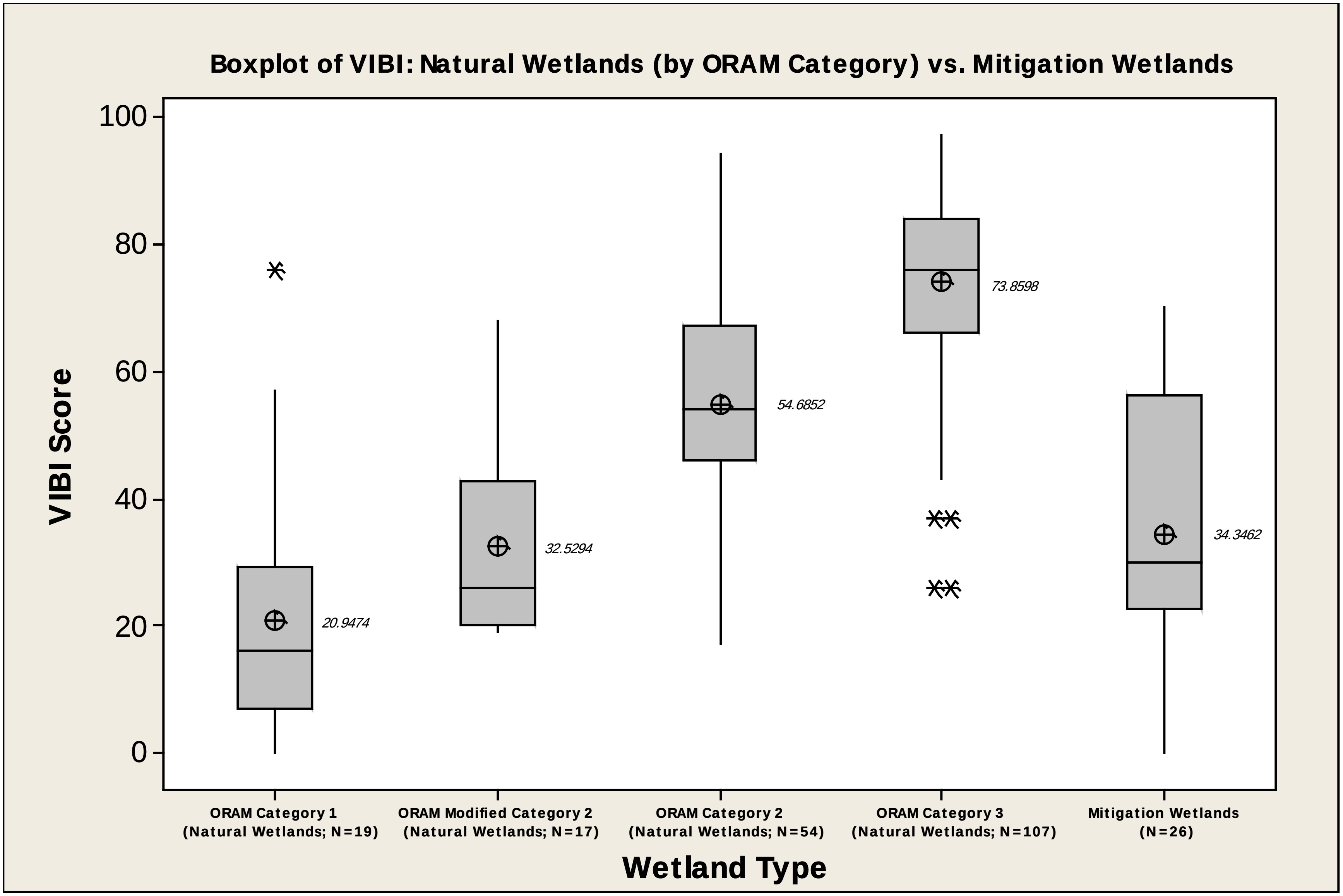

Figure 5. Box and whiskers plot comparing mean VIBI score for natural wetlands (by ORAM antidegradation category) with VIBI scores for mitigation wetlands (df = 222, F = 71.43, $p < 0.001$).

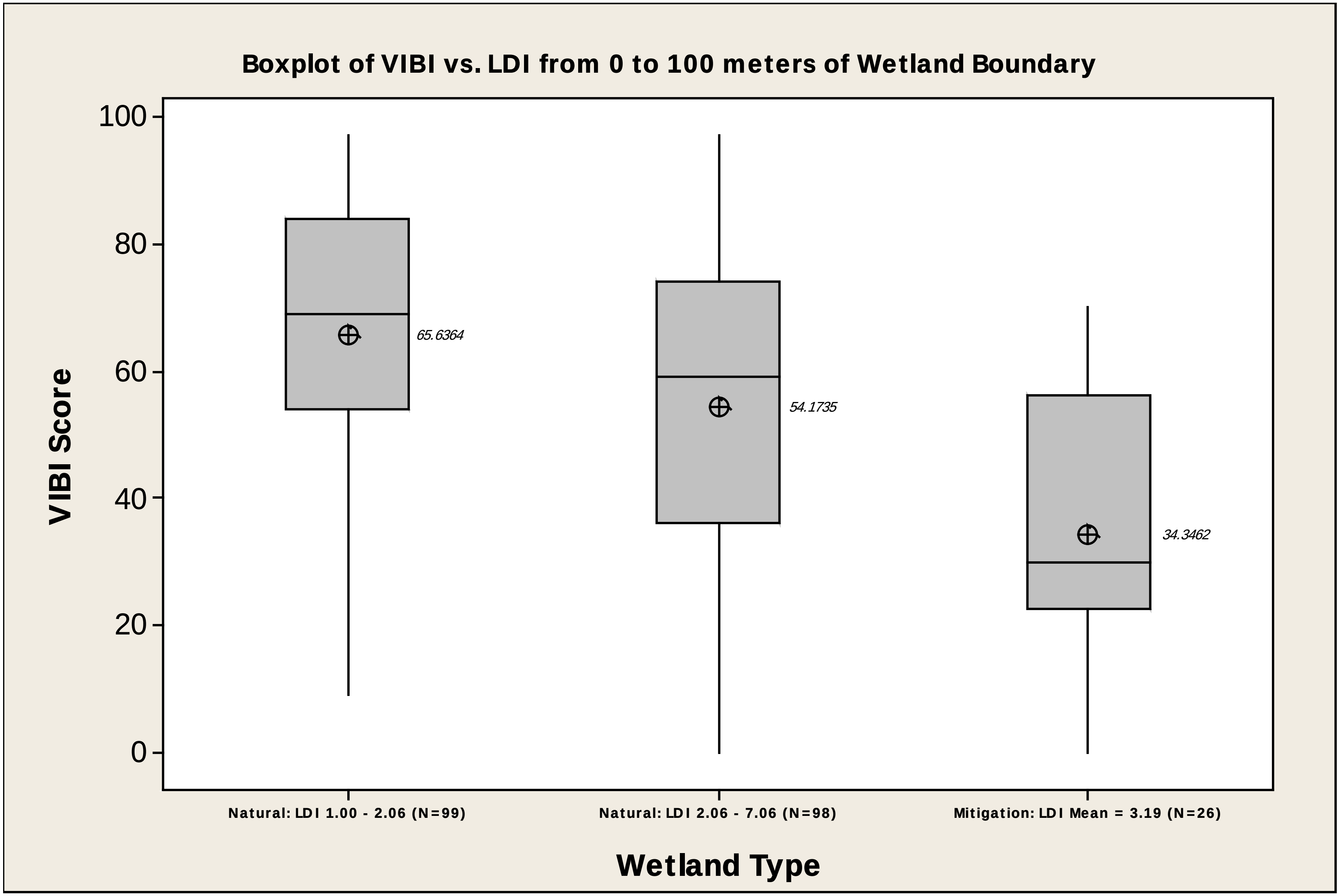

Figure 6. Box and whiskers plot comparing mean VIBI score for natural wetlands (divided into Low LDI and High LDI groups for area within 0 to 100 meters of wetland boundary) with VIBI scores for mitigation wetlands (df = 222, F = 20.11, $p < 0.001$).

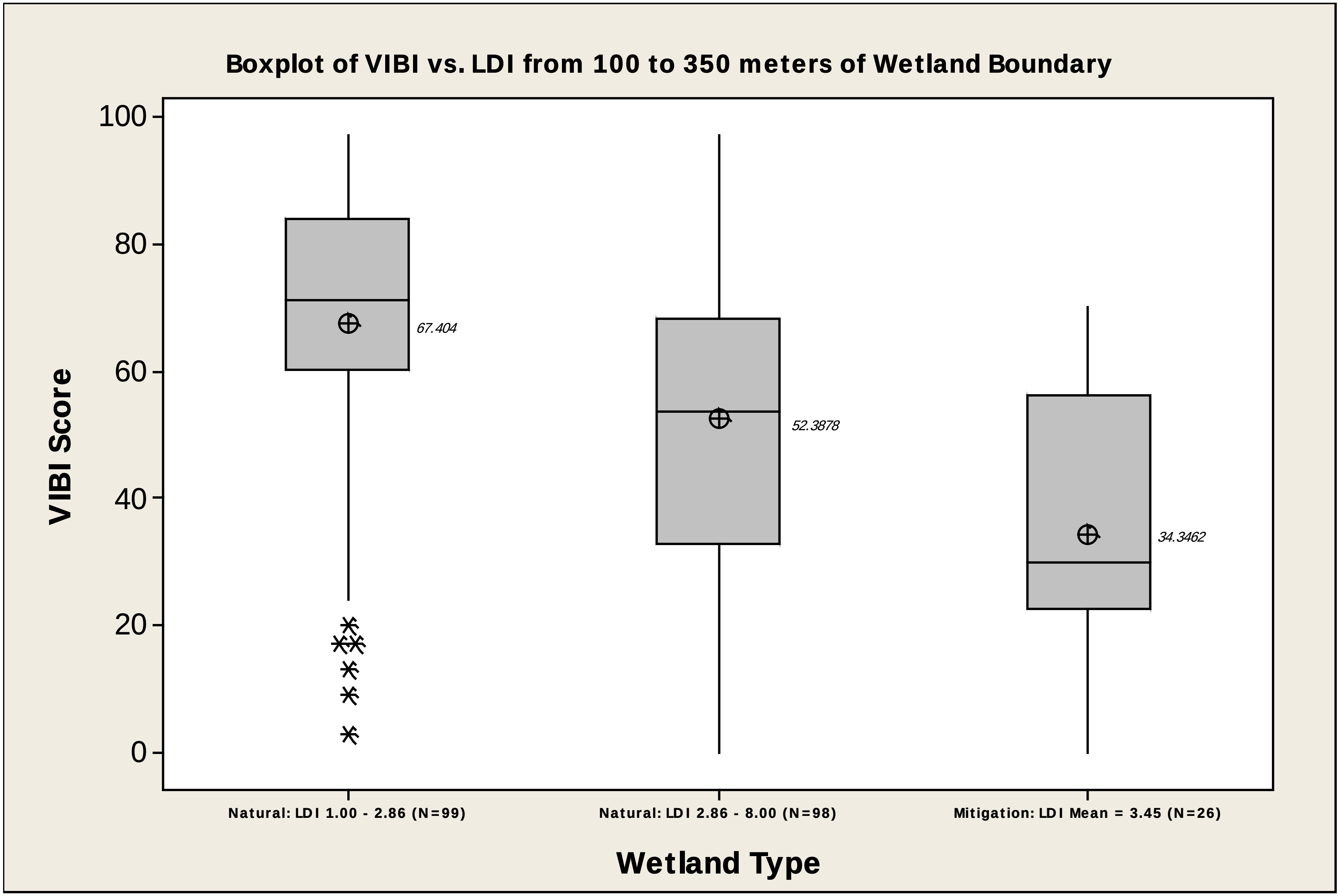

Figure 7. Box and whiskers plot comparing mean VIBI score for natural wetlands (divided into Low LDI and High LDI groups for area from 100 to 350 meters of wetland boundary) with VIBI scores for mitigation wetlands (df = 222, F = 25.45, p < 0.001).

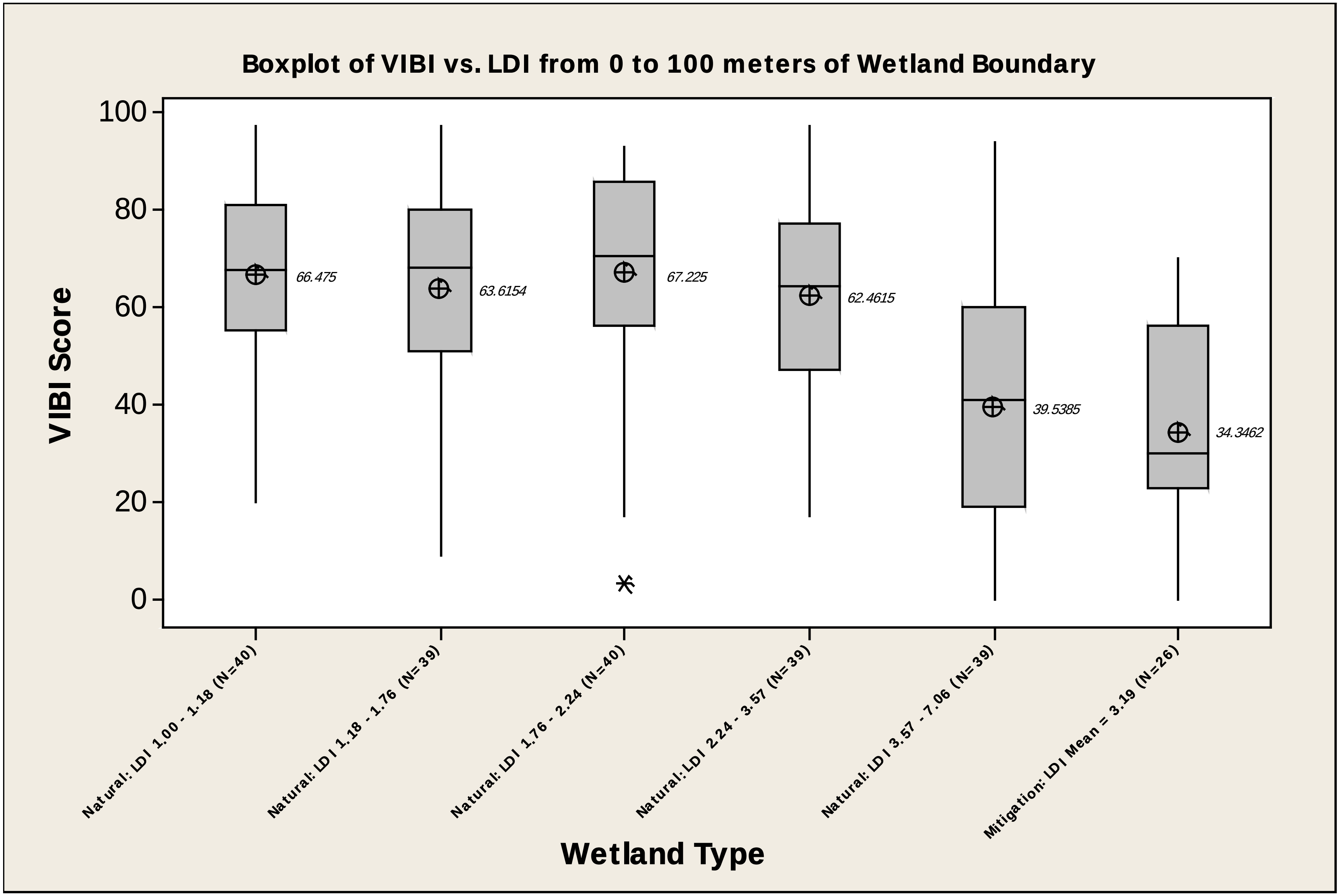

Figure 8. Box and whiskers plot comparing mean VIBI score for natural wetlands (divided into 5 equal LDI groups for area within 0 to 100 meters of wetland boundary) with VIBI scores for mitigation wetlands (df = 222, F = 15.08, $p < 0.001$).

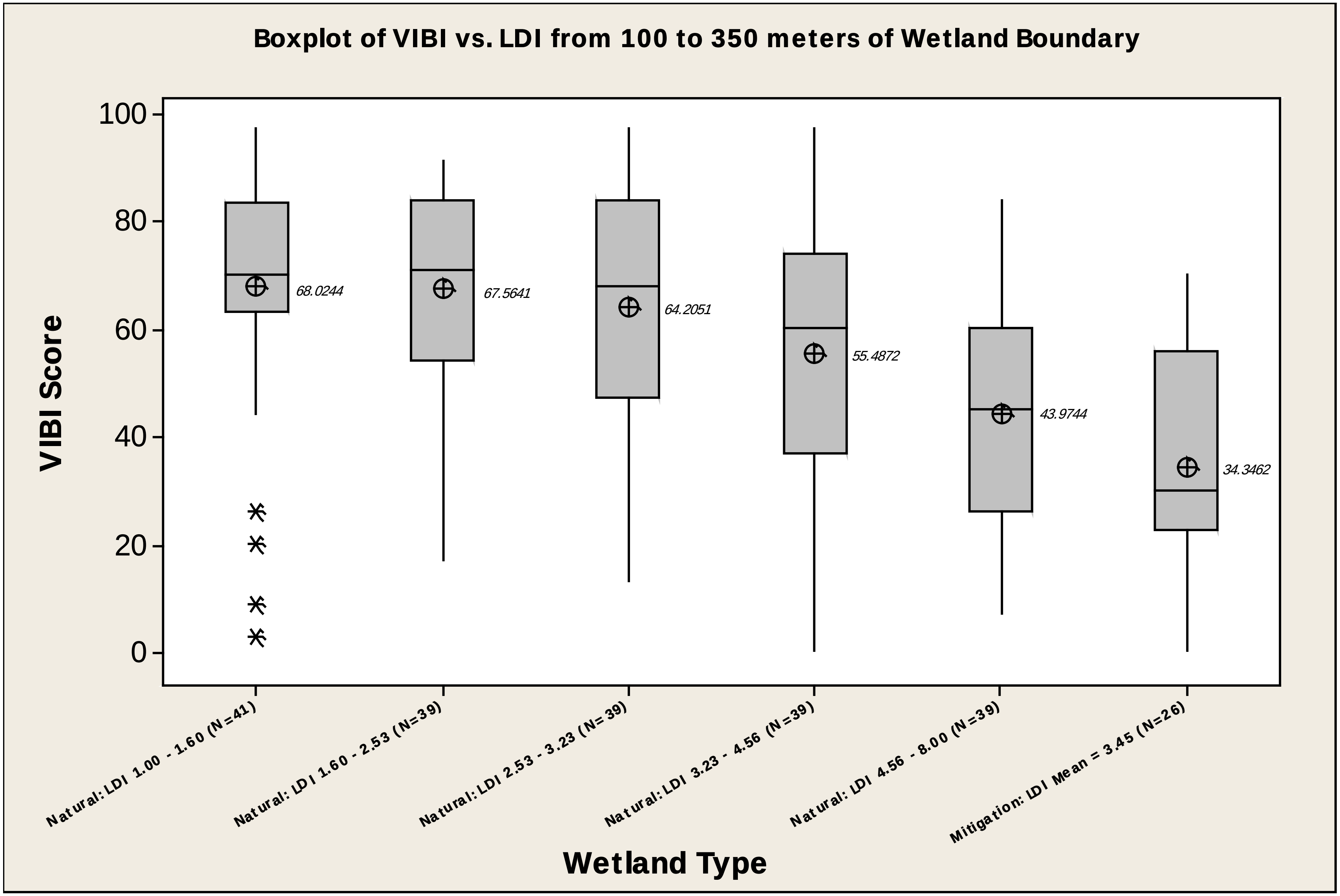

Figure 9. Box and whiskers plot comparing mean VIBI score for natural wetlands (divided into 5 equal LDI groups for area from 100 to 350 meters of wetland boundary) with VIBI scores for mitigation wetlands (df = 222, F = 12.65, $p < 0.001$).

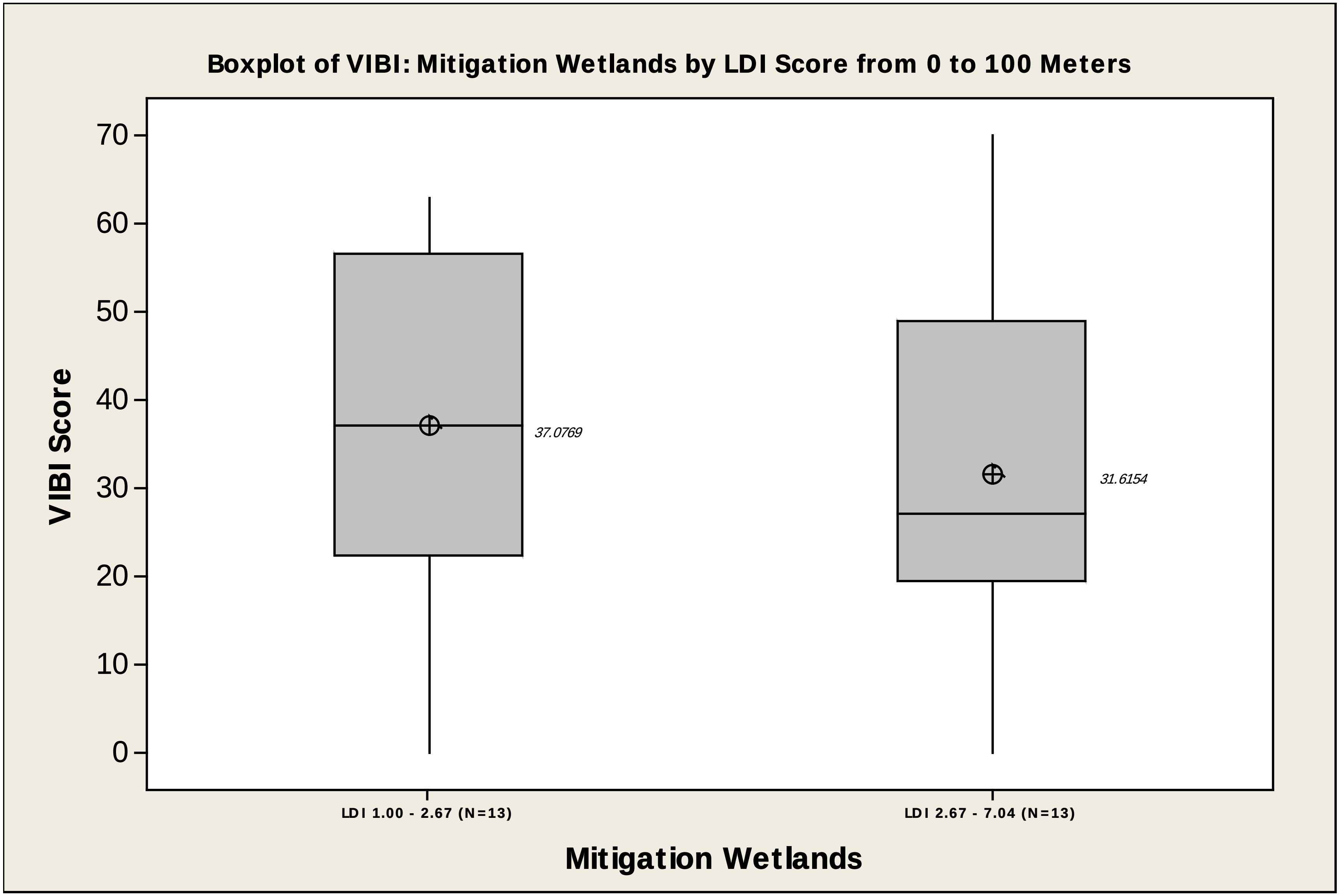

Figure 10. Box and whiskers plot comparing mean VIBI score for mitigation wetlands divided into Low LDI and High LDI groups for area within 0 to 100 meters of wetland boundary (df = 25, F = 0.49, p = 0.489).

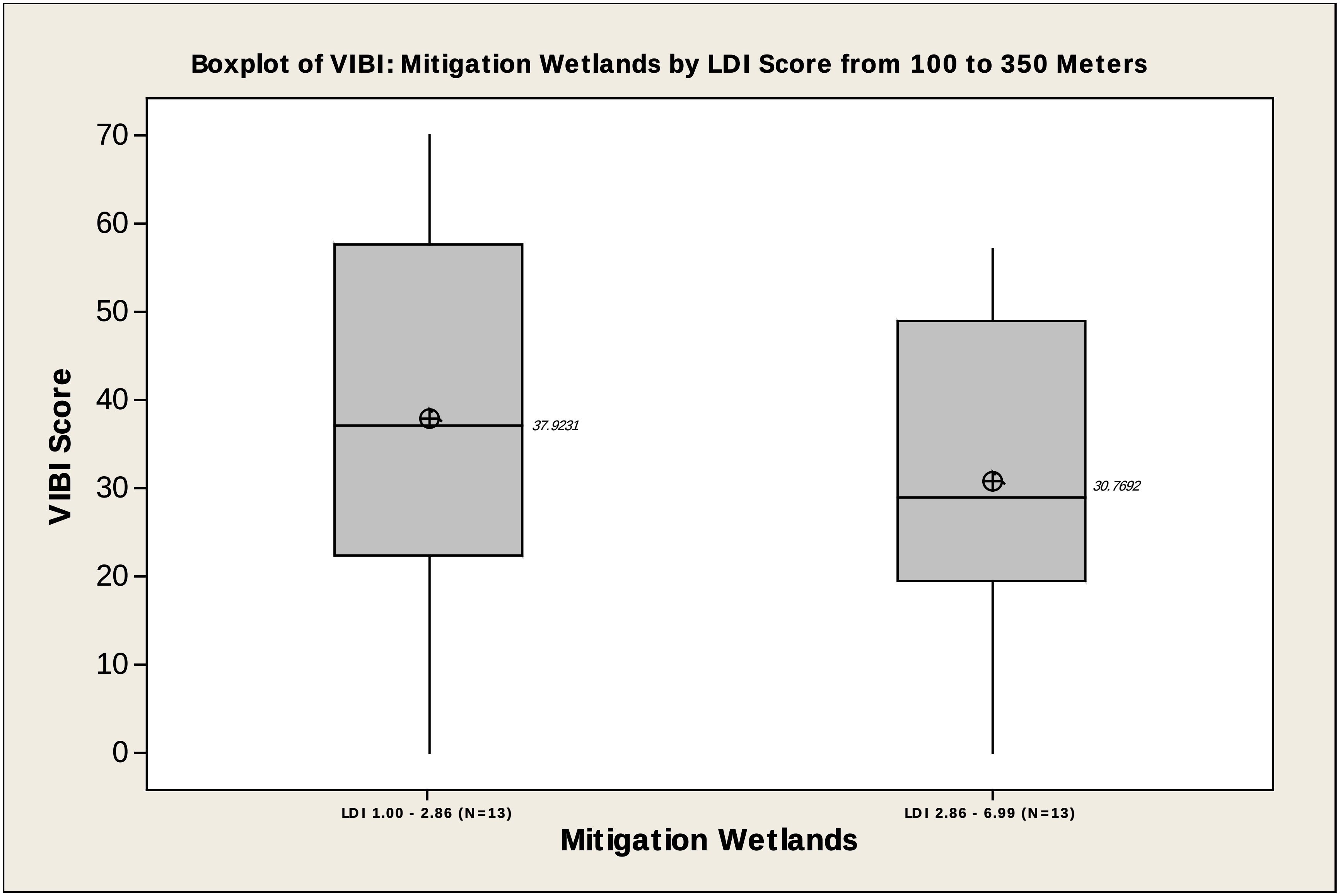

Figure 11. Box and whiskers plot comparing mean VIBI score for mitigation wetlands divided into Low LDI and High LDI groups for area from 100 to 350 meters of wetland boundary (df = 25, F = 0.86, p = 0.363).

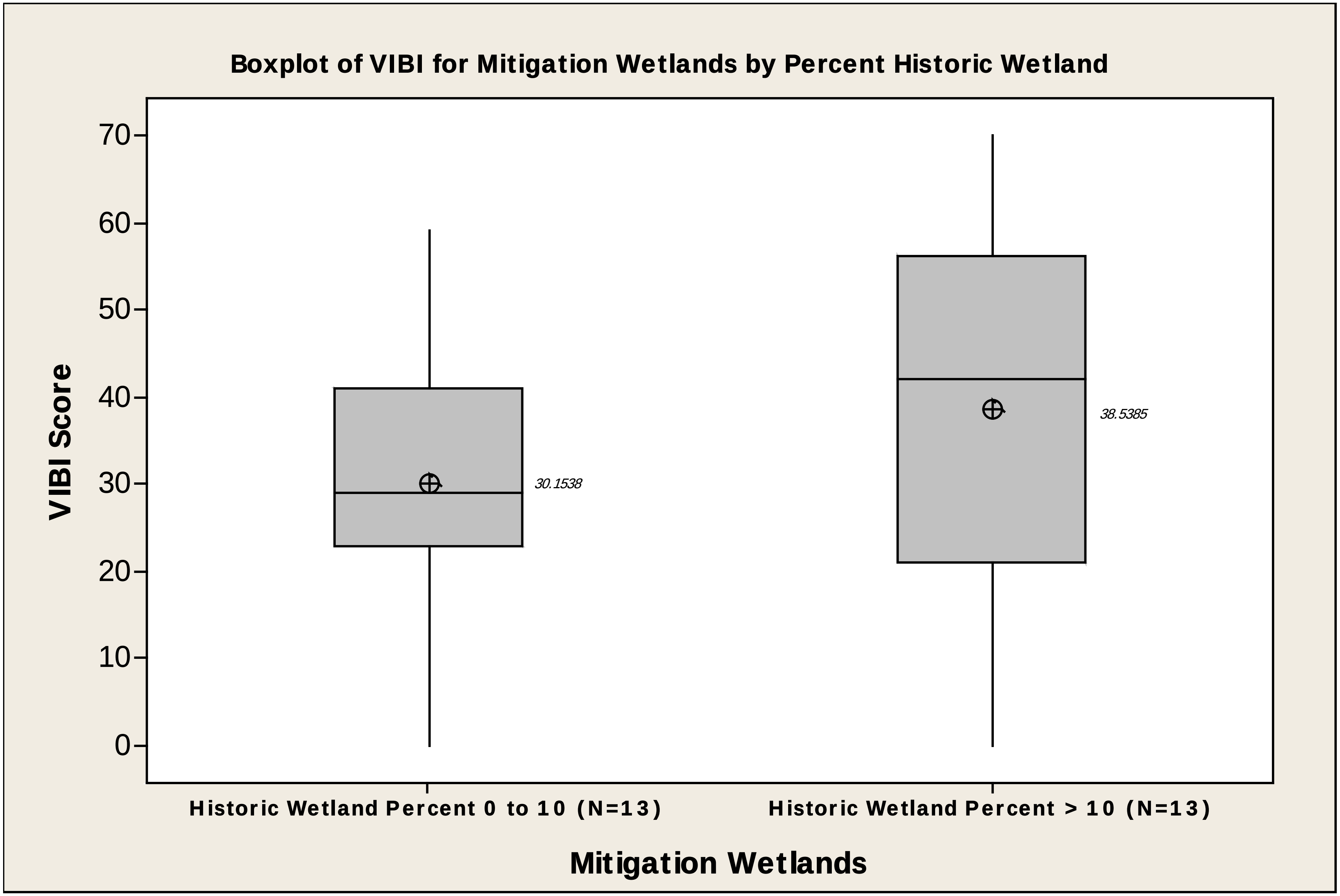

Figure 12. Box and whiskers plot comparing mean VIBI score for mitigation wetlands broken down by estimated percent historic wetland (df = 25, F = 1.20, p = 0.284).

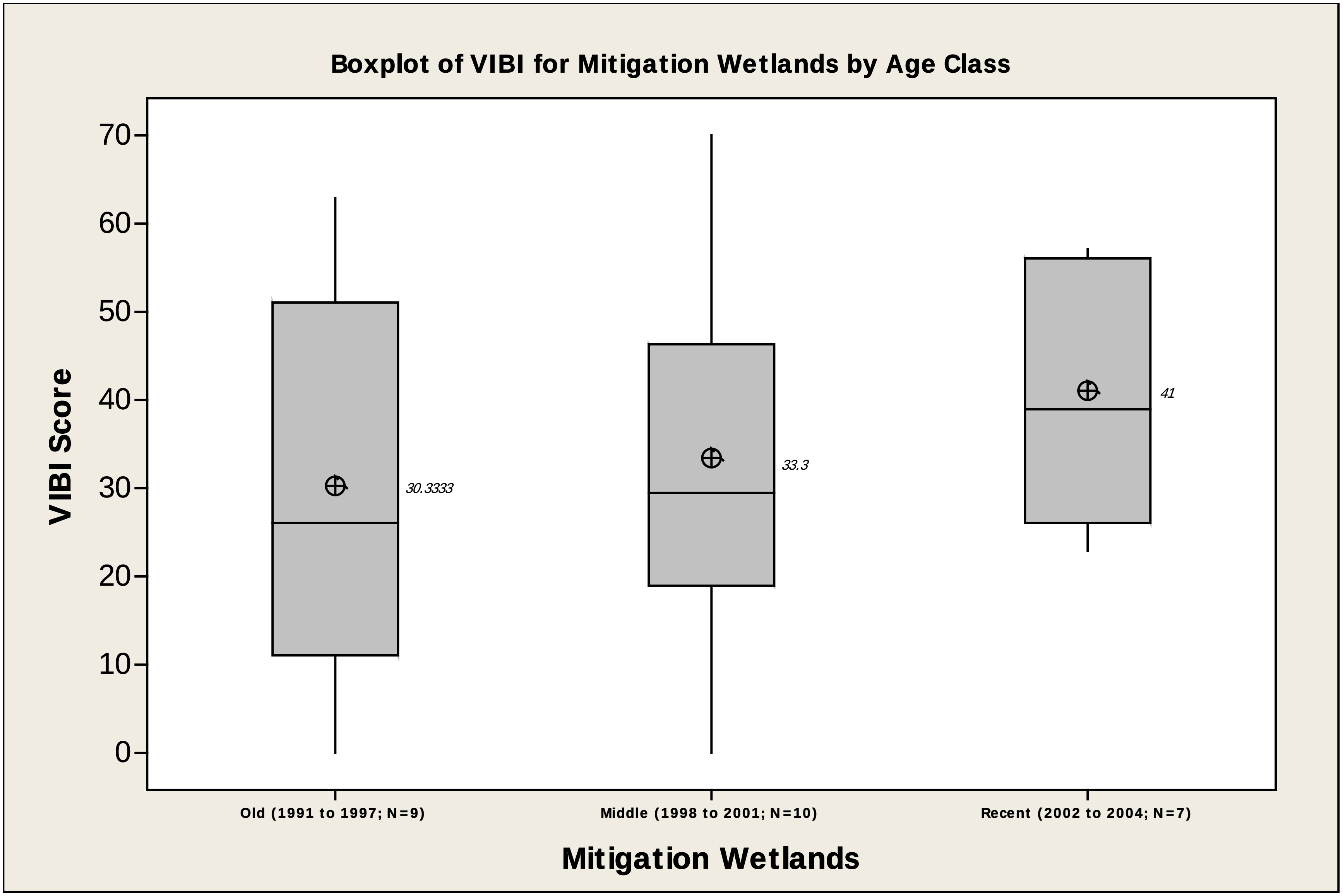

Figure 13. Box and whiskers plot comparing mean VIBI score for mitigation wetlands broken down by three age classes (df = 25, F = 0.59, p = 0.565).

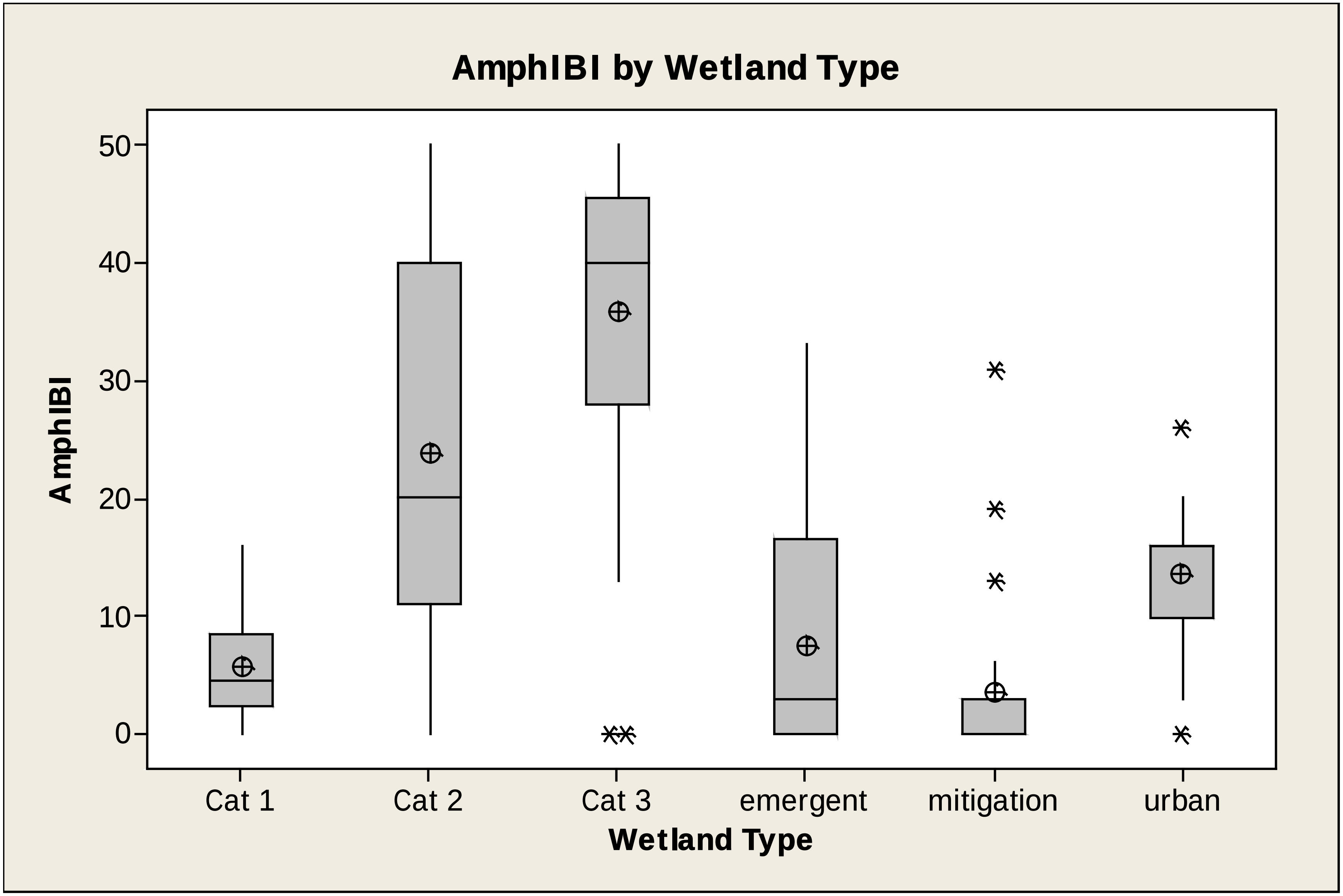

Figure 14. Box and whiskers plot comparing AmphIBI total scores, median scores and mean scores by wetand type. The top of box is at the 75th percentile, the bottom of the box is at the 25th percentile, lines within the box are the medians, circles with crosses are means.

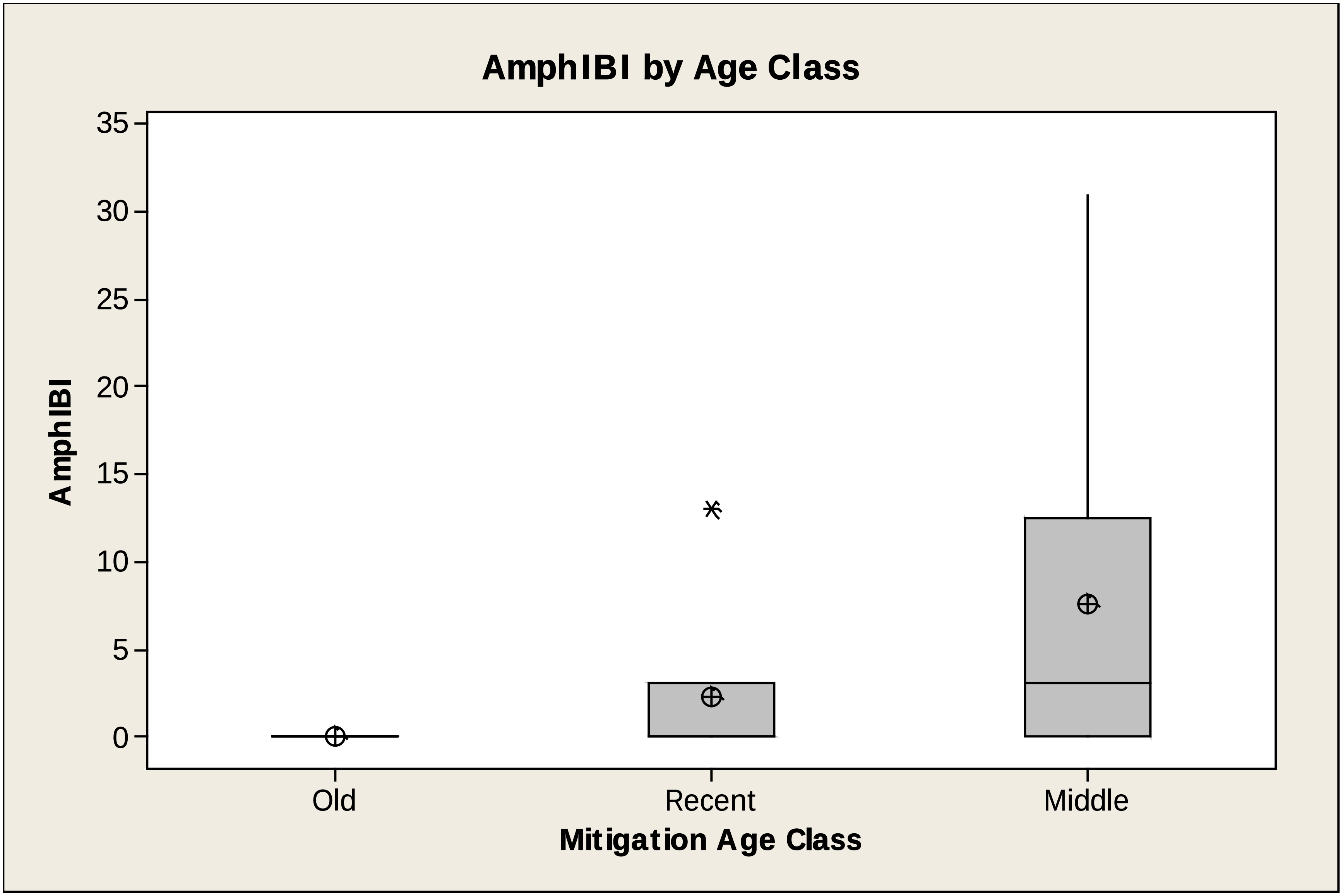

Figure 15. Box and whiskers plot comparing AmphIBI total scores, median scores and mean scores by age class of the mitigation wetlands. The top of box is at the 75th percentile, the bottom of the box is at the 25th percentile, lines within the box are the medians, circles with crosses are means.

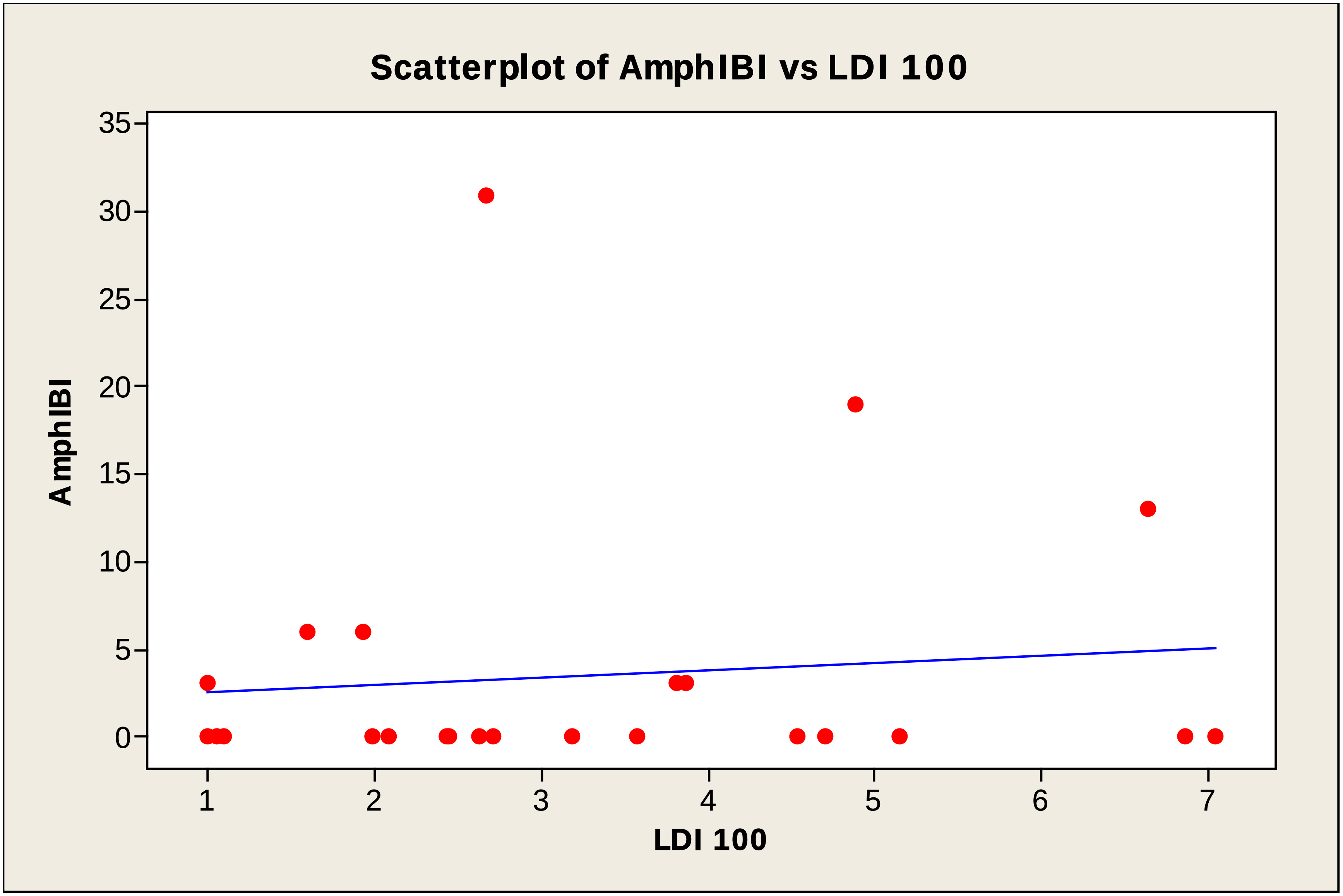

Figure 16. Scatterplot with a fitted line of AmphIBI scores by LDI scores for the areas 0 to 100 meters from the mitigation wetland boundaries.

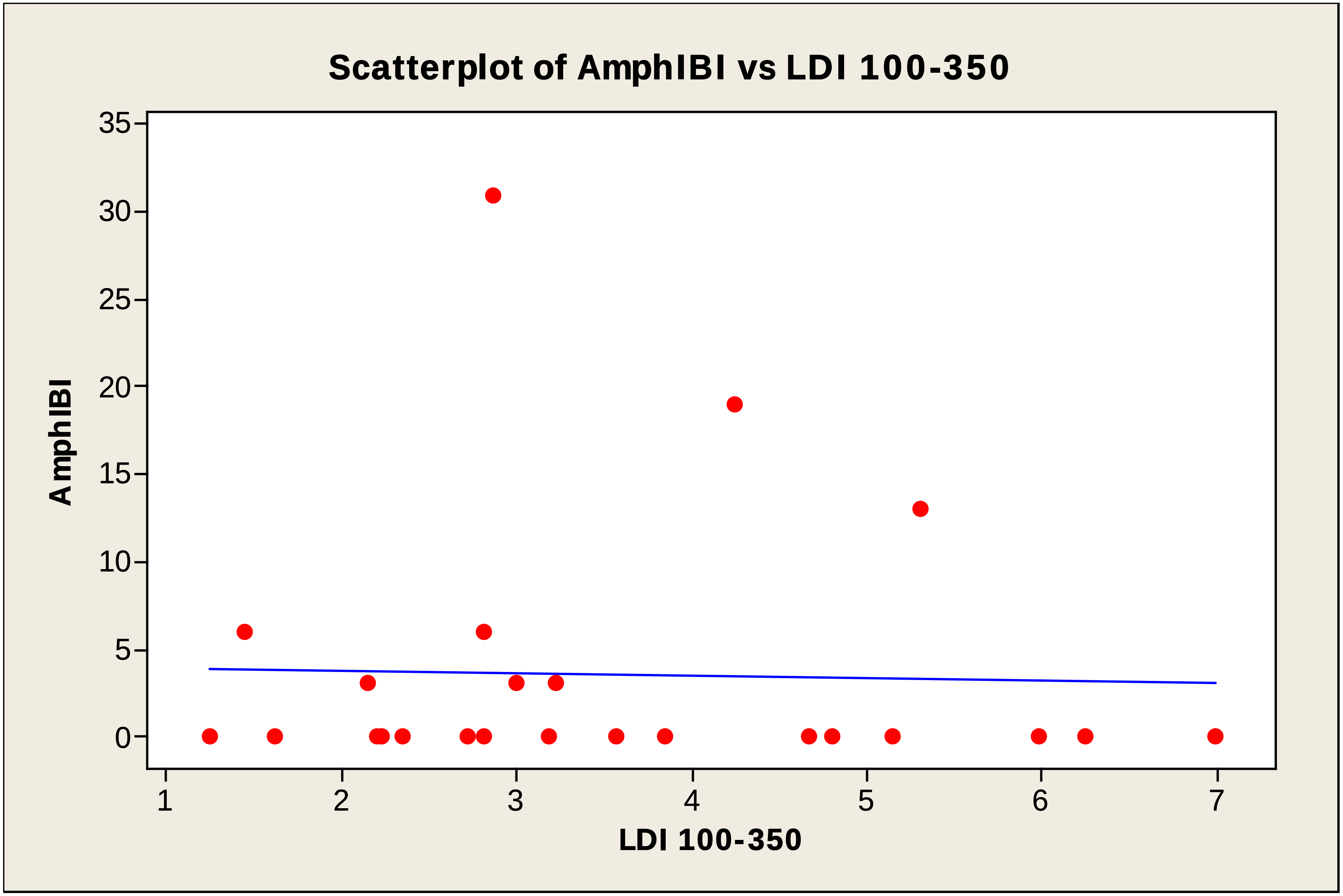

Figure 17. Scatterplot with a fitted line of AmphIBI scores by LDI scores for the areas 100 to 350 meters from the mitigation wetland boundaries.

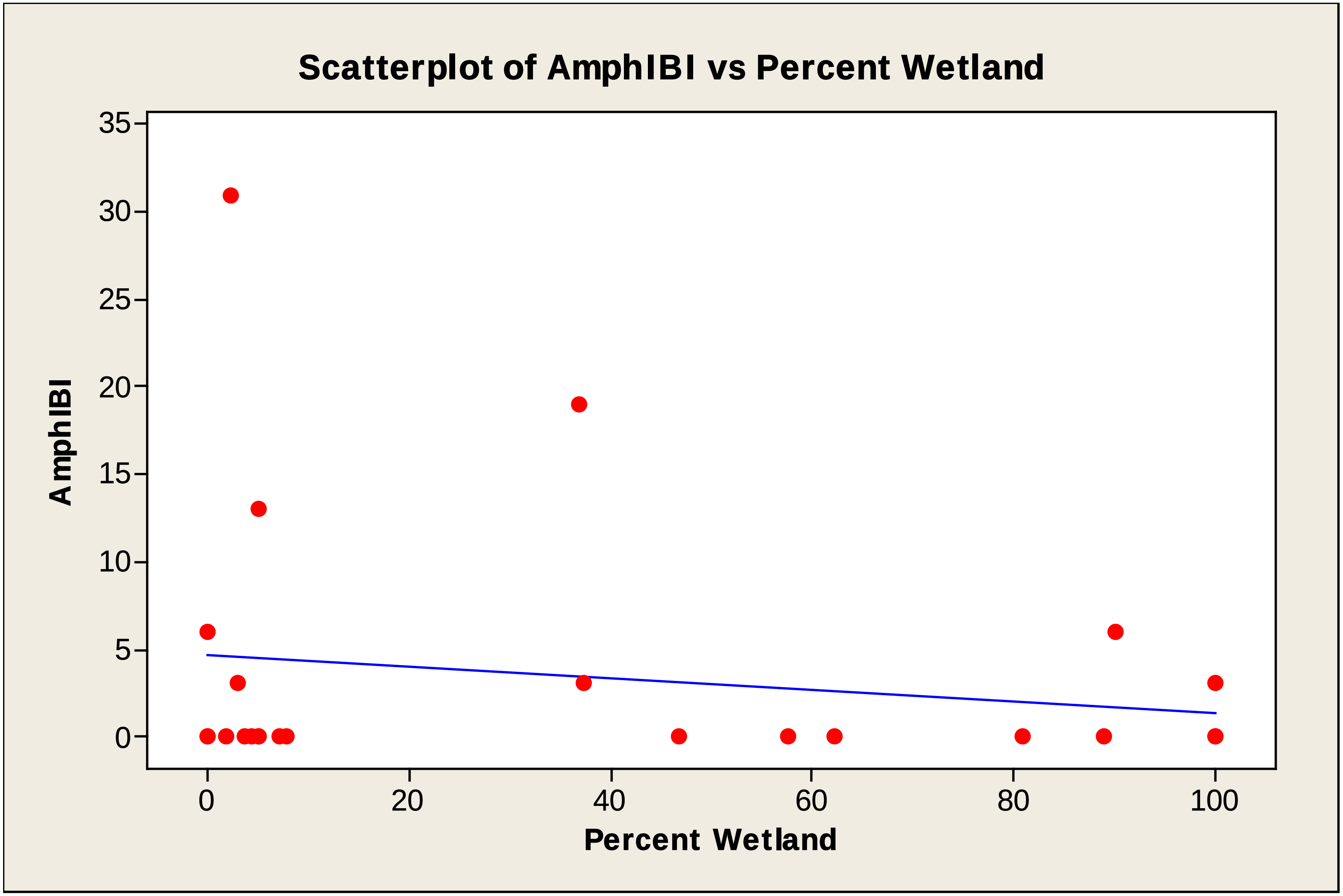

Figure 18. Scatterplot with a fitted line of AmphIBI scores by percent hydric soil in mitigation wetland footprint.

Figure 19. Admore Drive mitigation site, Portage County, Ohio.

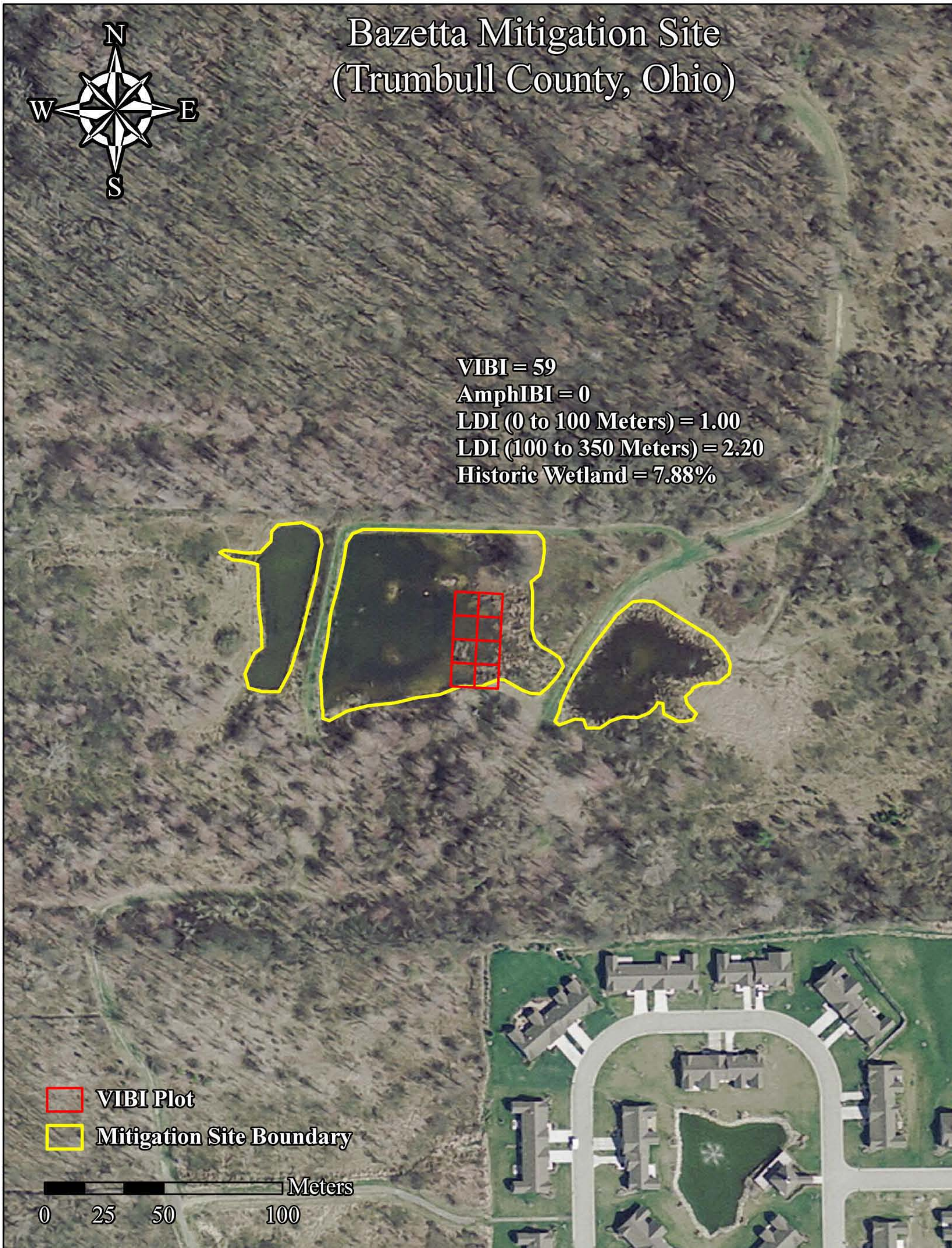

Figure 20. Bazetta mitigation site, Trumbull County, Ohio.

Figure 21. BFI mitigation site, Lorain County, Ohio.

Figure 22. Brookside Park mitigation site, Cuyahoga County, Ohio.

Figure 23. Cambridge mitigation site, Guernsey County, Ohio.

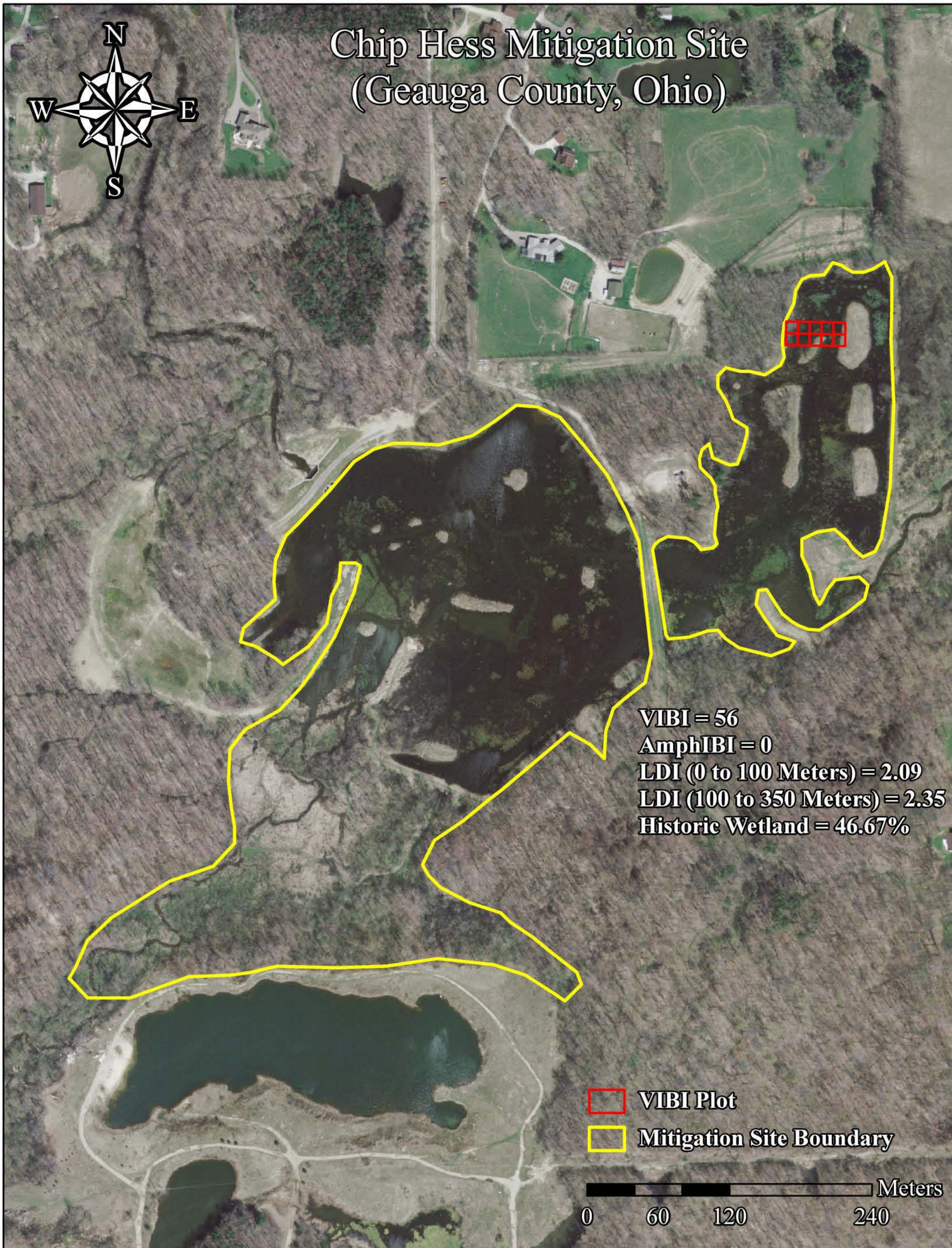

Figure 24. Chip Hess mitigation site, Geauga County, Ohio.

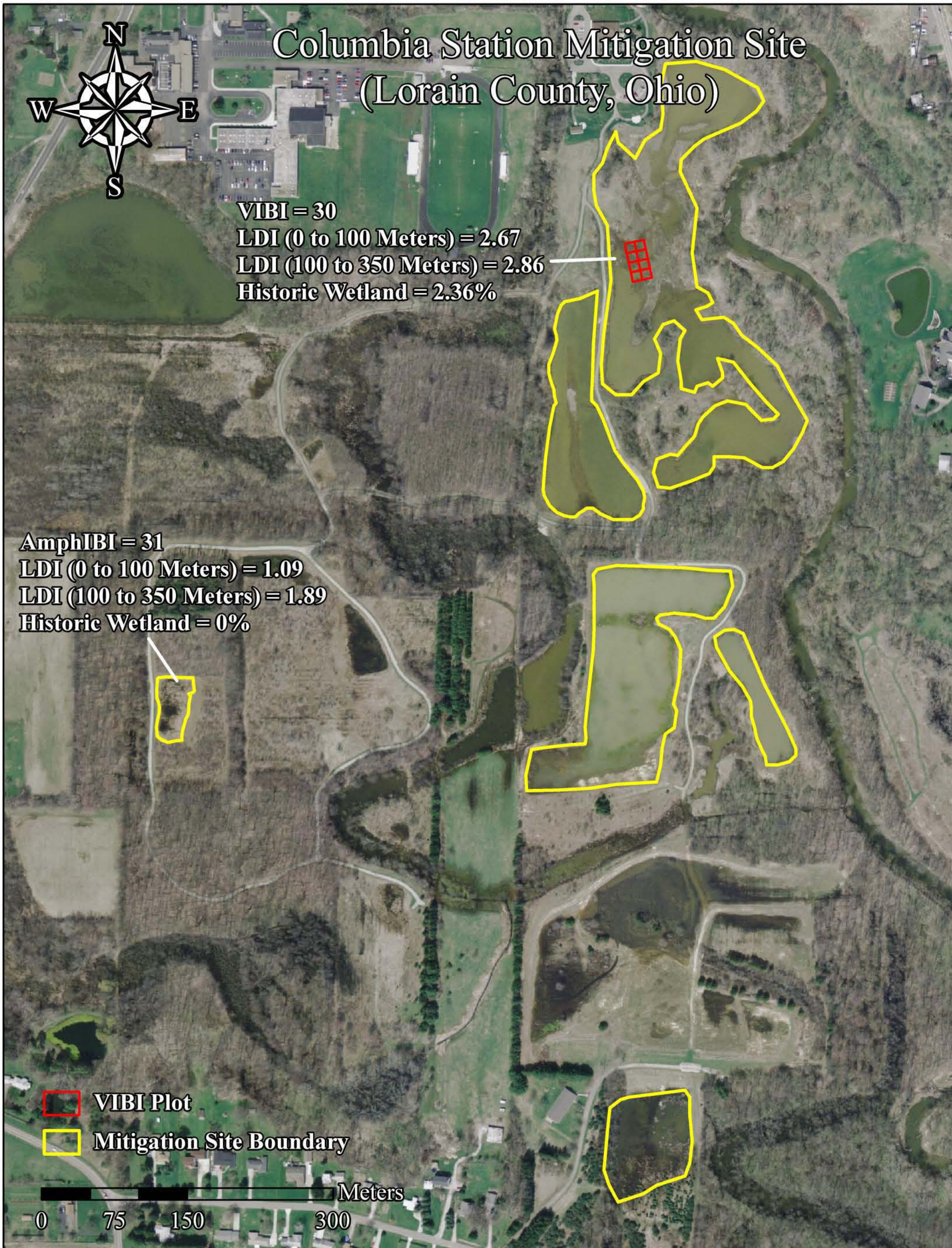

Figure 25. Columbia North mitigation site, Lorain County, Ohio.

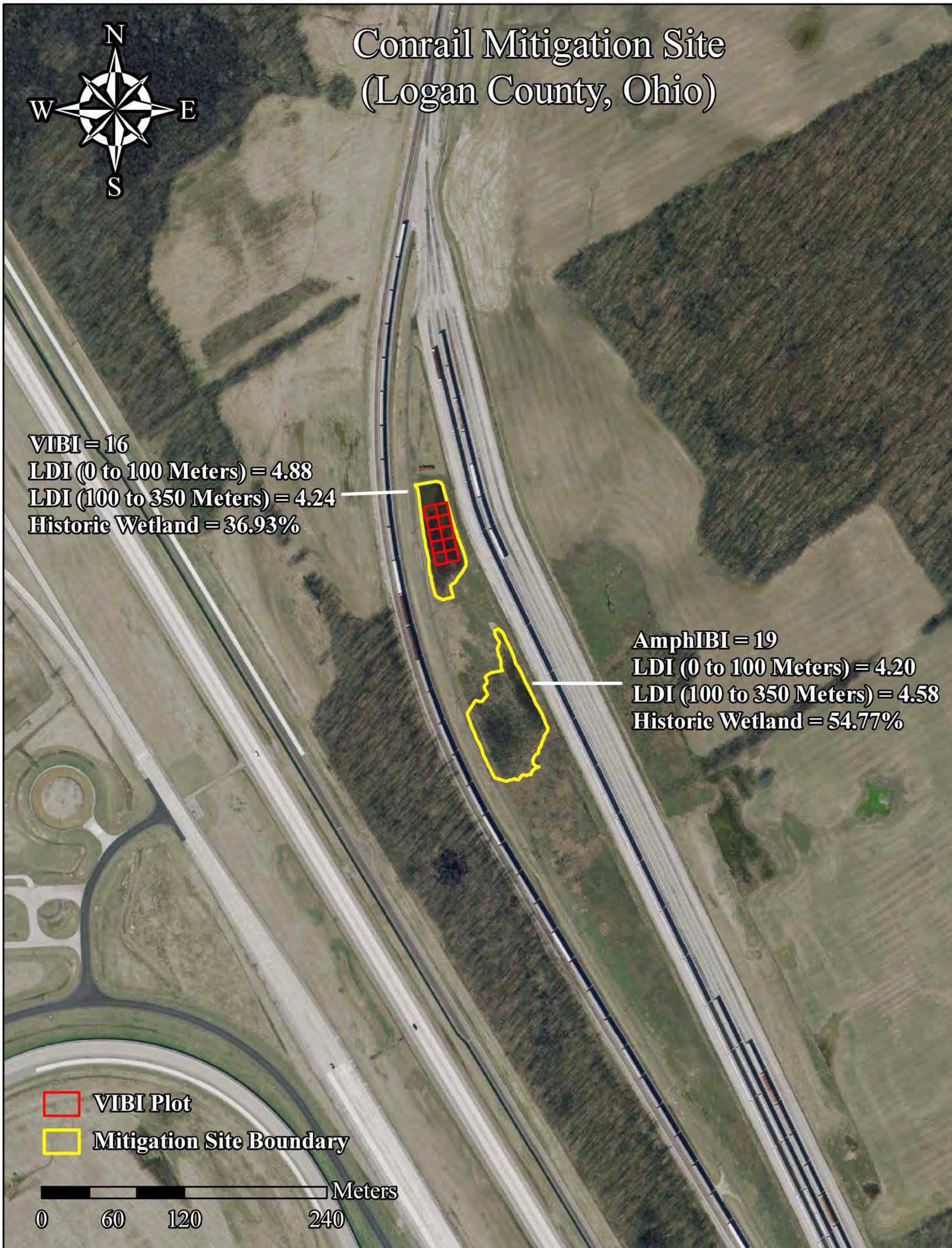

Figure 26. Conrail mitigation site, Logan County, Ohio.

Figure 27. Danis mitigation site, Clark County, Ohio.

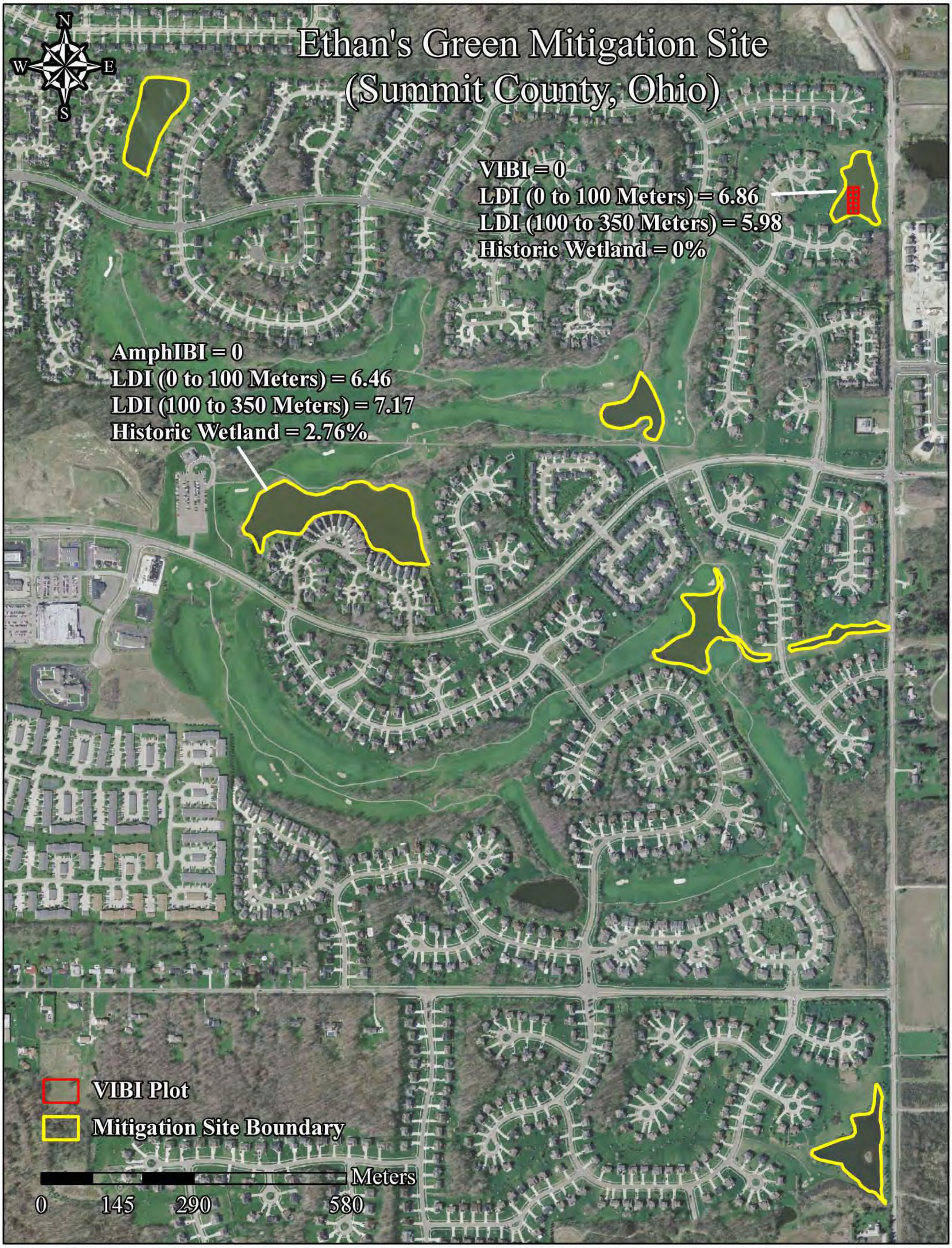

Figure 28. Ethan's Green mitigation site, Summit County, Ohio.

Figure 29. Flying J mitigation site, Trumbull County, Ohio.

Figure 30. Girdled Road mitigation site, Lake County, Ohio.

Figure 31. Golden Links mitigation site, Summit County, Ohio.

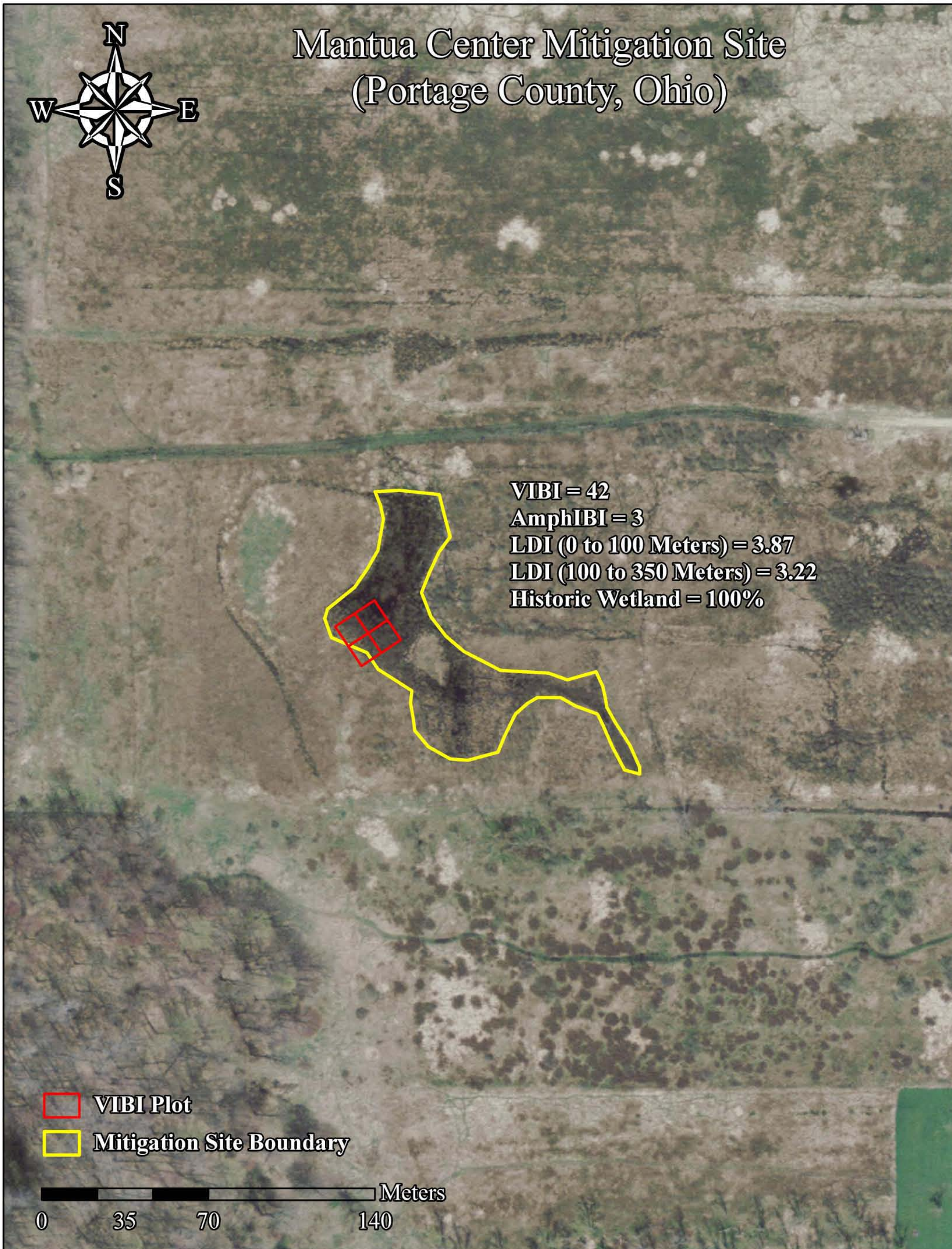

Figure 32. Mantua Center mitigation site, Portage County, Ohio.

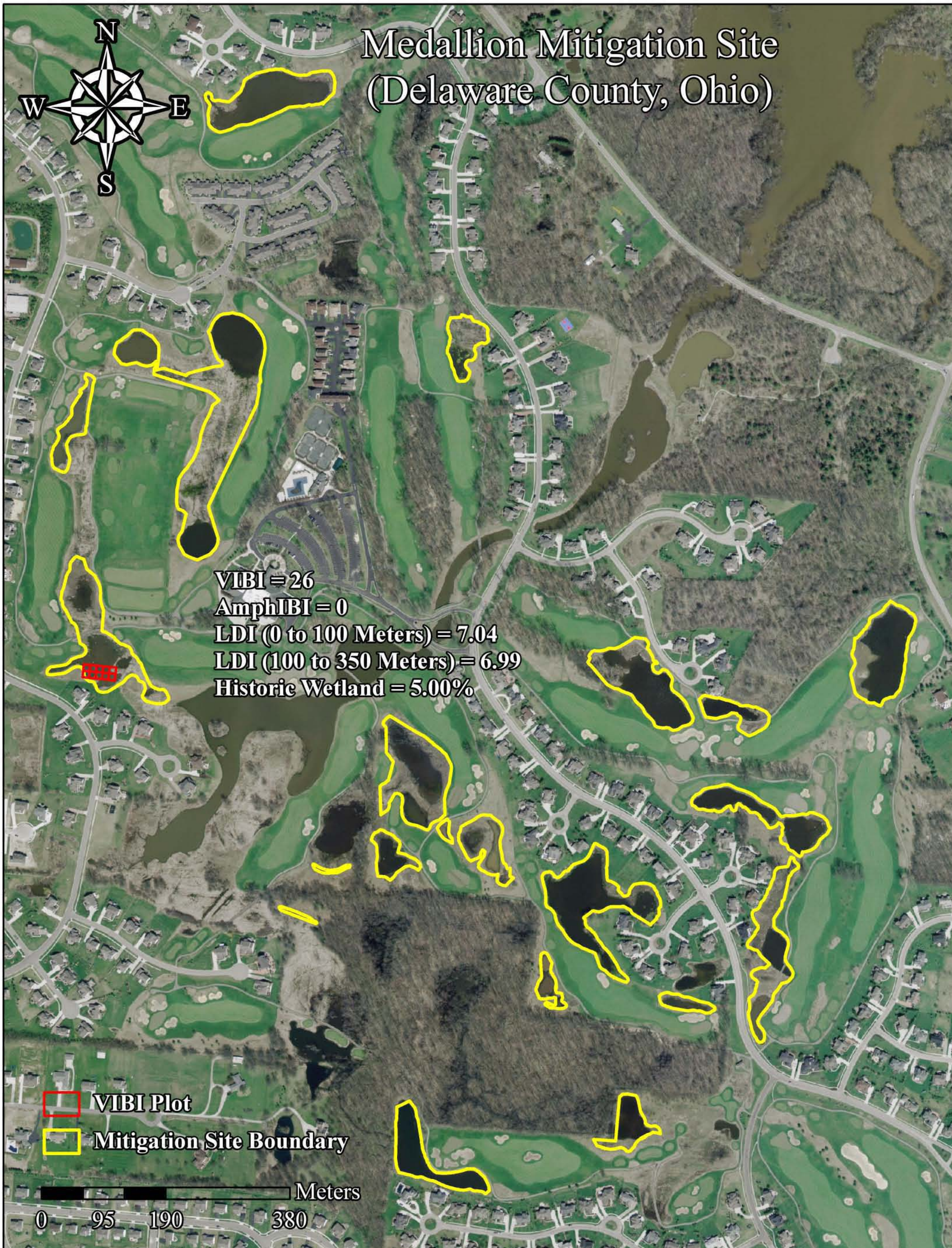

Figure 33. Medallion mitigation site, Delaware County, Ohio.

Figure 34. Mud Bog mitigation site, Summit County, Ohio.

Figure 35. Penney Nature Preserve mitigation site, Defiance County, Ohio.

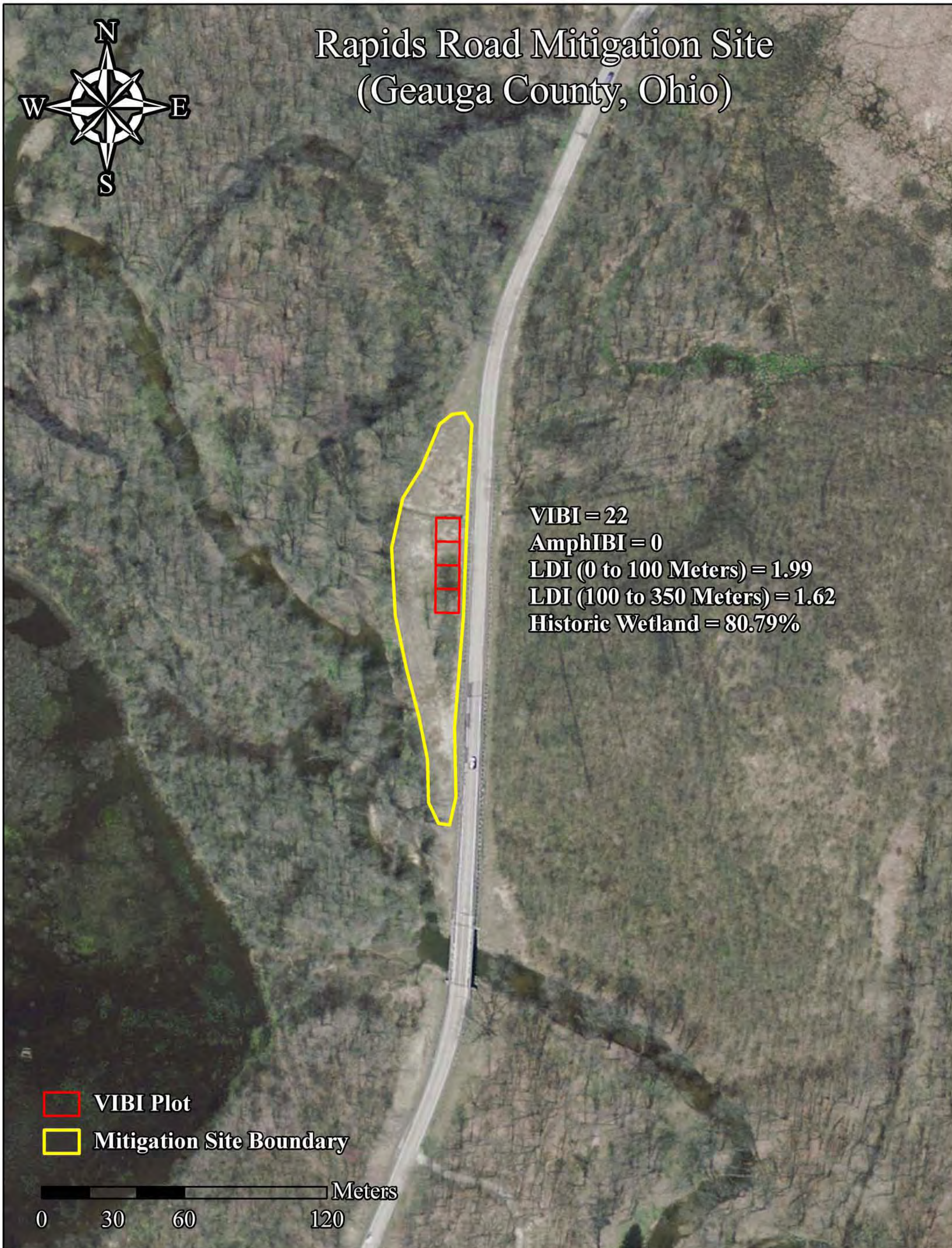

Figure 36. Rapids Road mitigation site, Geauga County, Ohio.

Figure 37. R&F Coal mitigation site, Belmont County, Ohio.

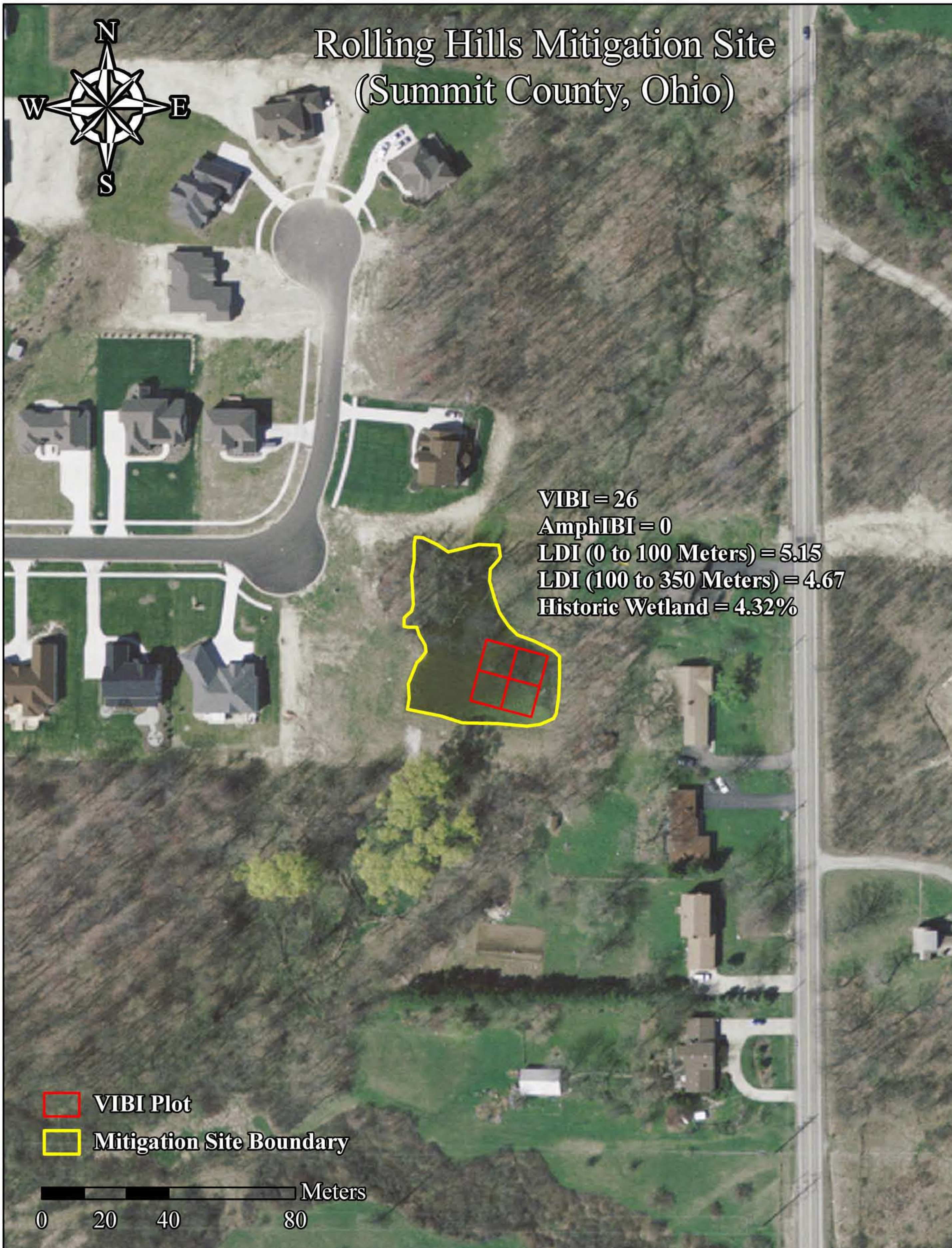

Figure 38. Rolling Hills mitigation site, Summit County, Ohio.

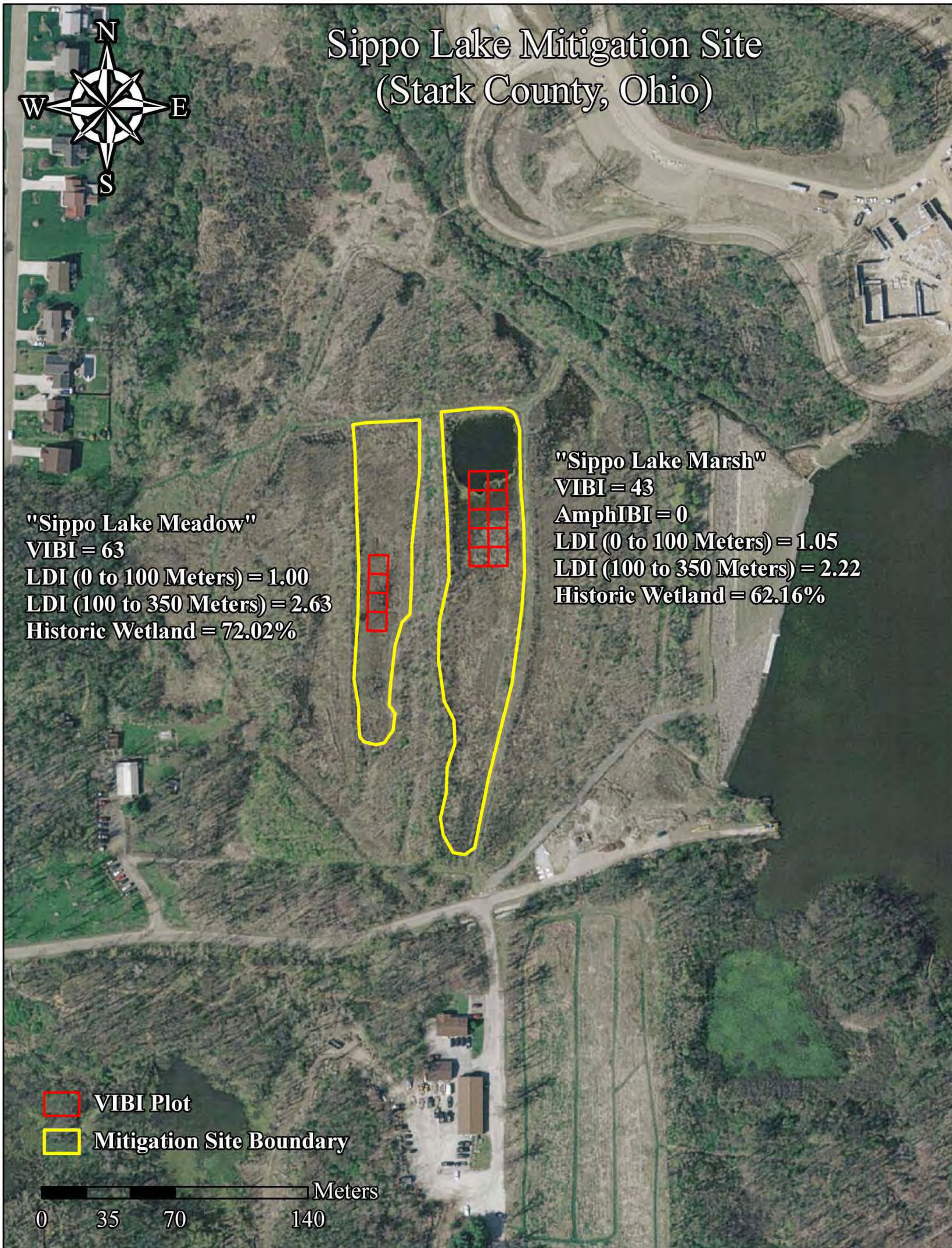

Figure 39. Sippo Lake Meadow and Sippo Lake Marsh mitigation sites, Stark County, Ohio.

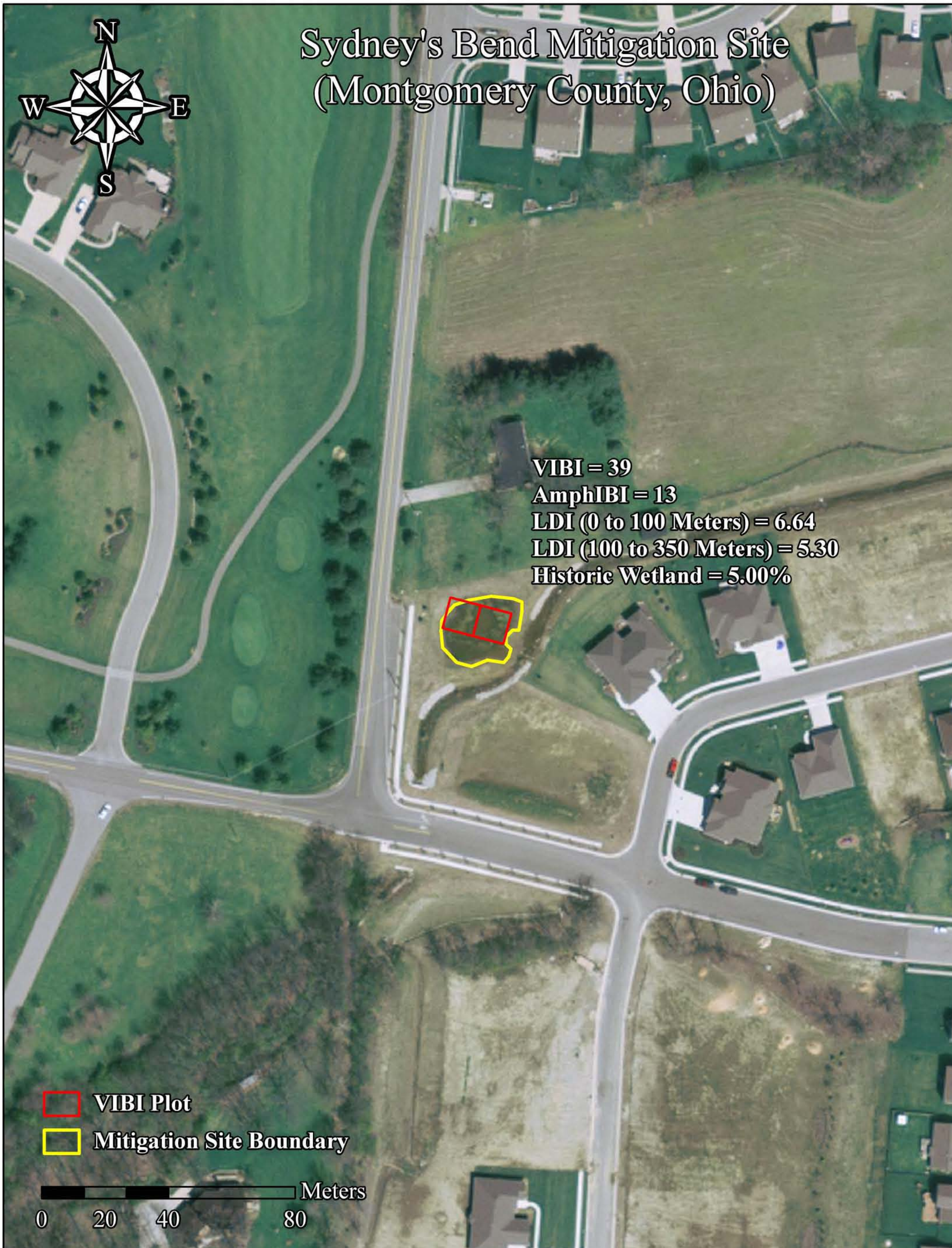

Figure 40. Sydney's Bend mitigation site, Montgomery County, Ohio.

Figure 41. Wal Mart mitigation site, Mahoning County, Ohio.

Figure 42. Willow Point mitigation site, Erie County, Ohio.

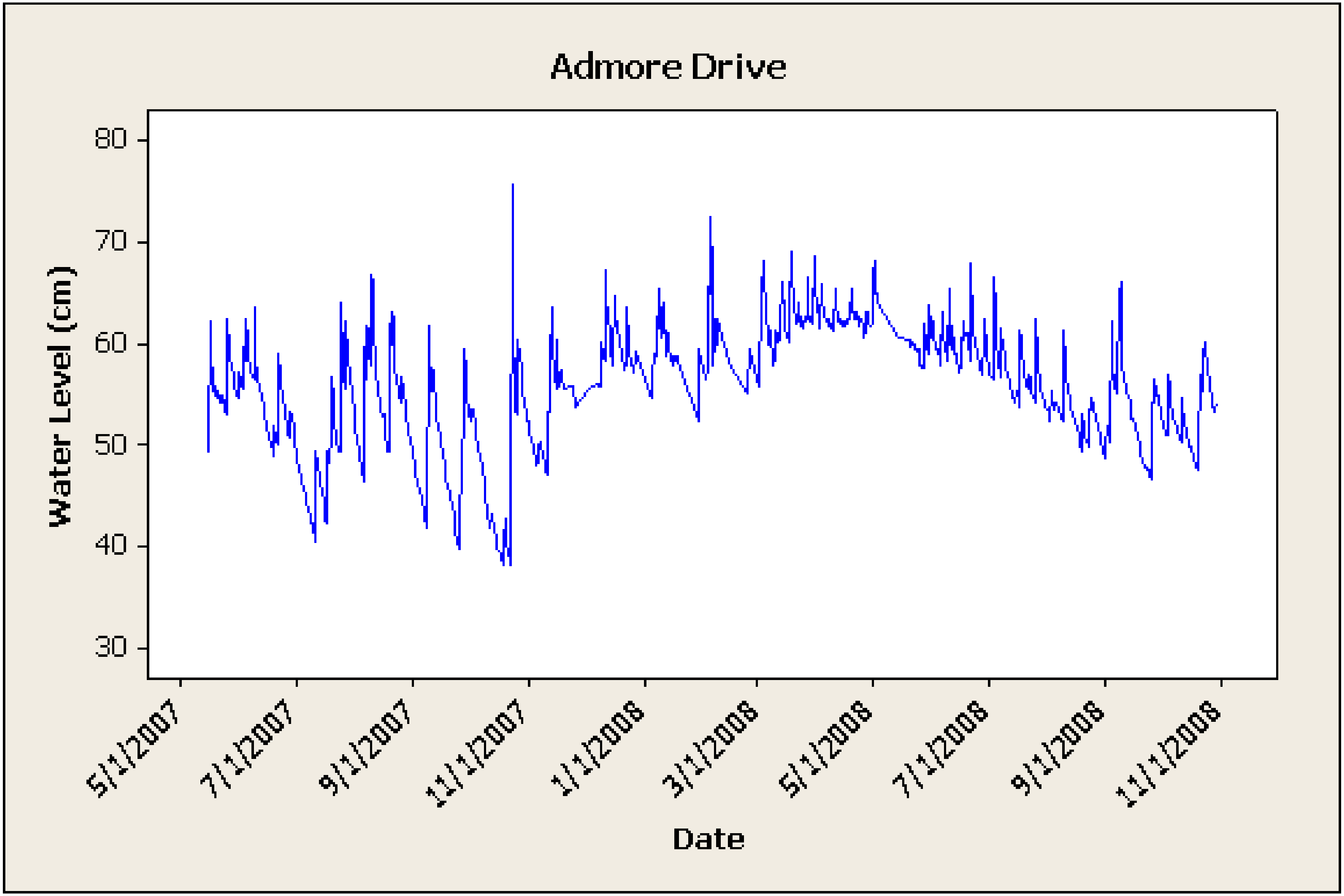

Figure 43. Admore Drive mitigation site (Portage County, Ohio) hydrograph, developed from monitoring well data.

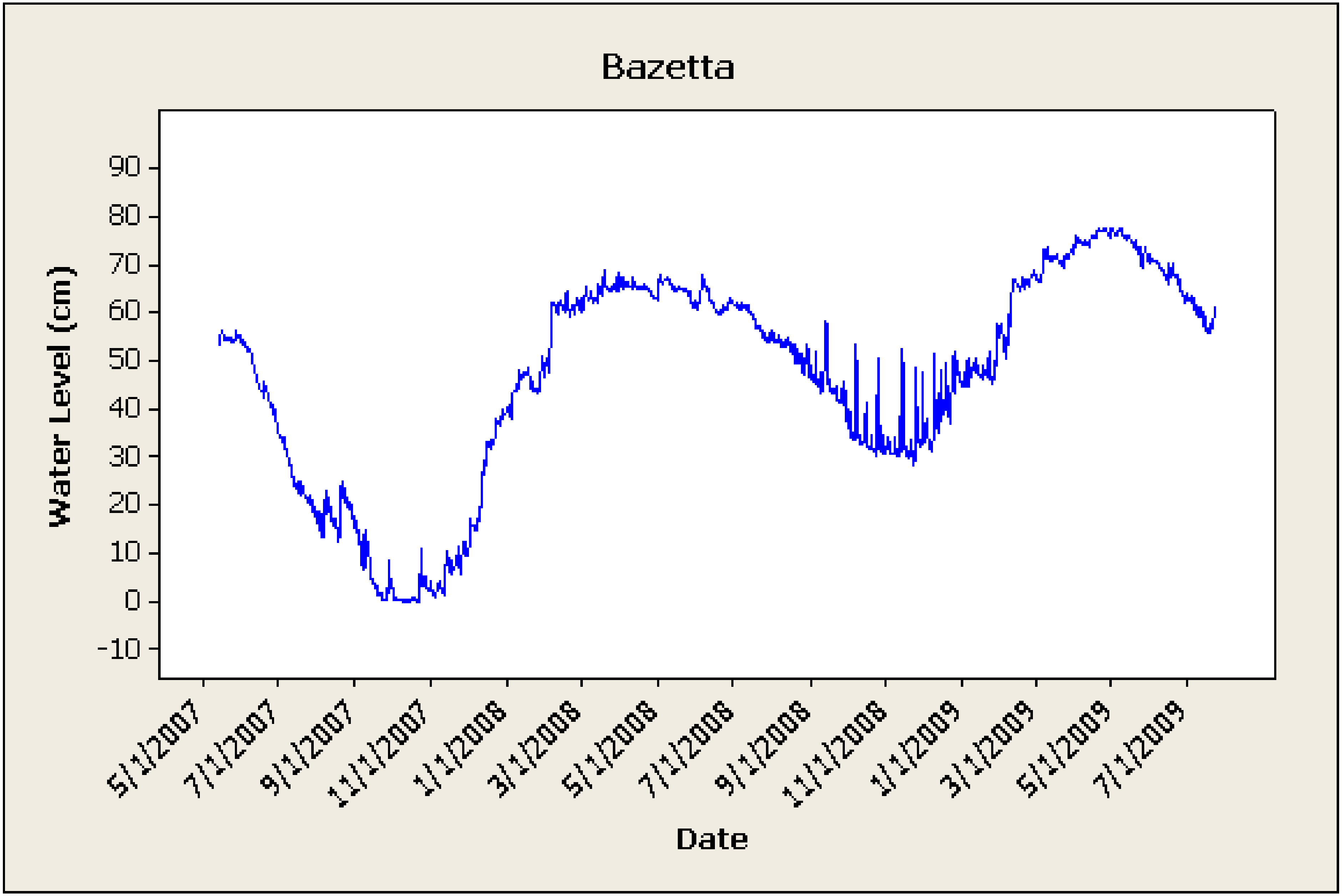

Figure 44. Bazetta mitigation site (Trumbull County, Ohio) hydrograph, developed from monitoring well data.

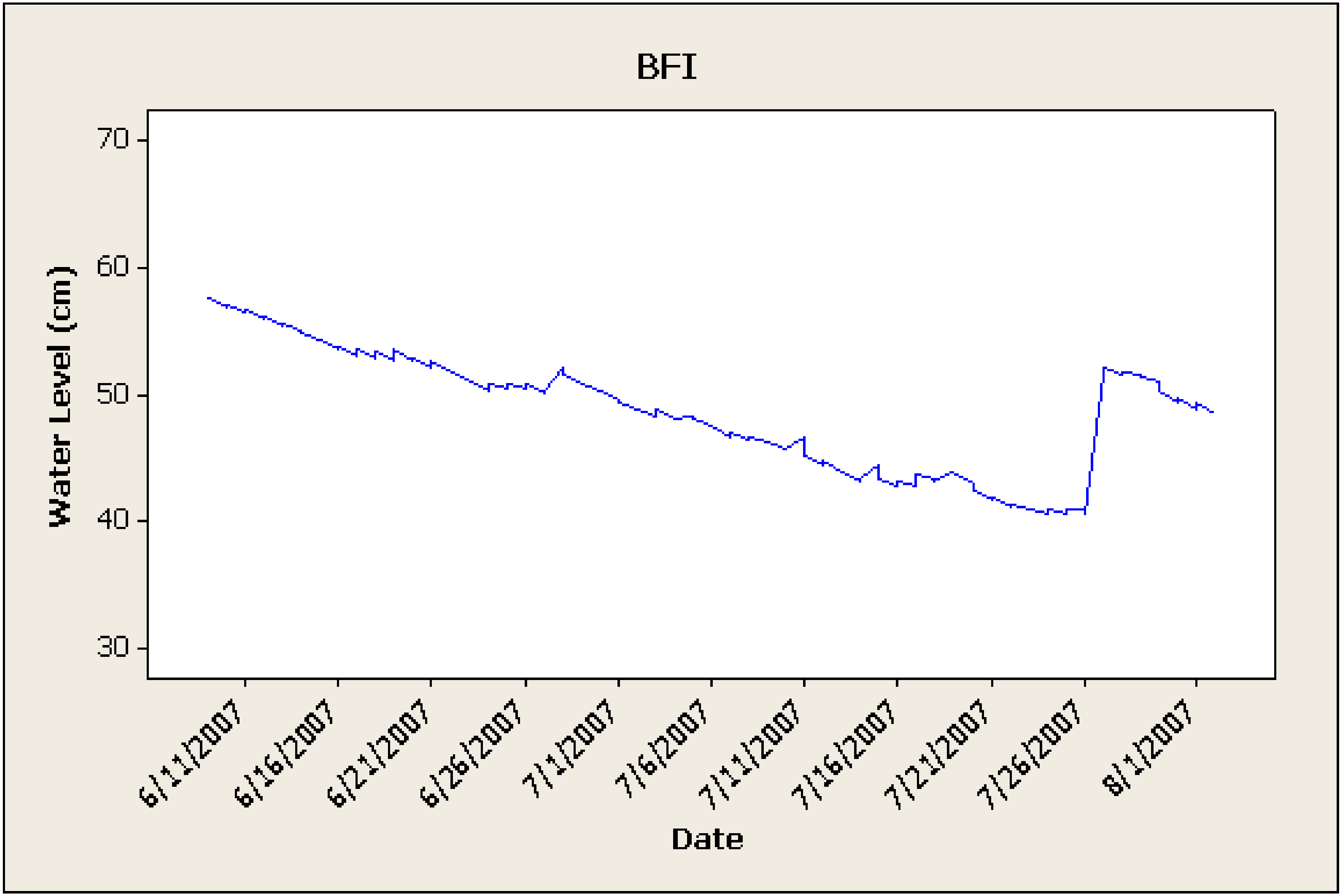

Figure 45. BFI mitigation site (Lorain County, Ohio) hydrograph, developed from monitoring well data.

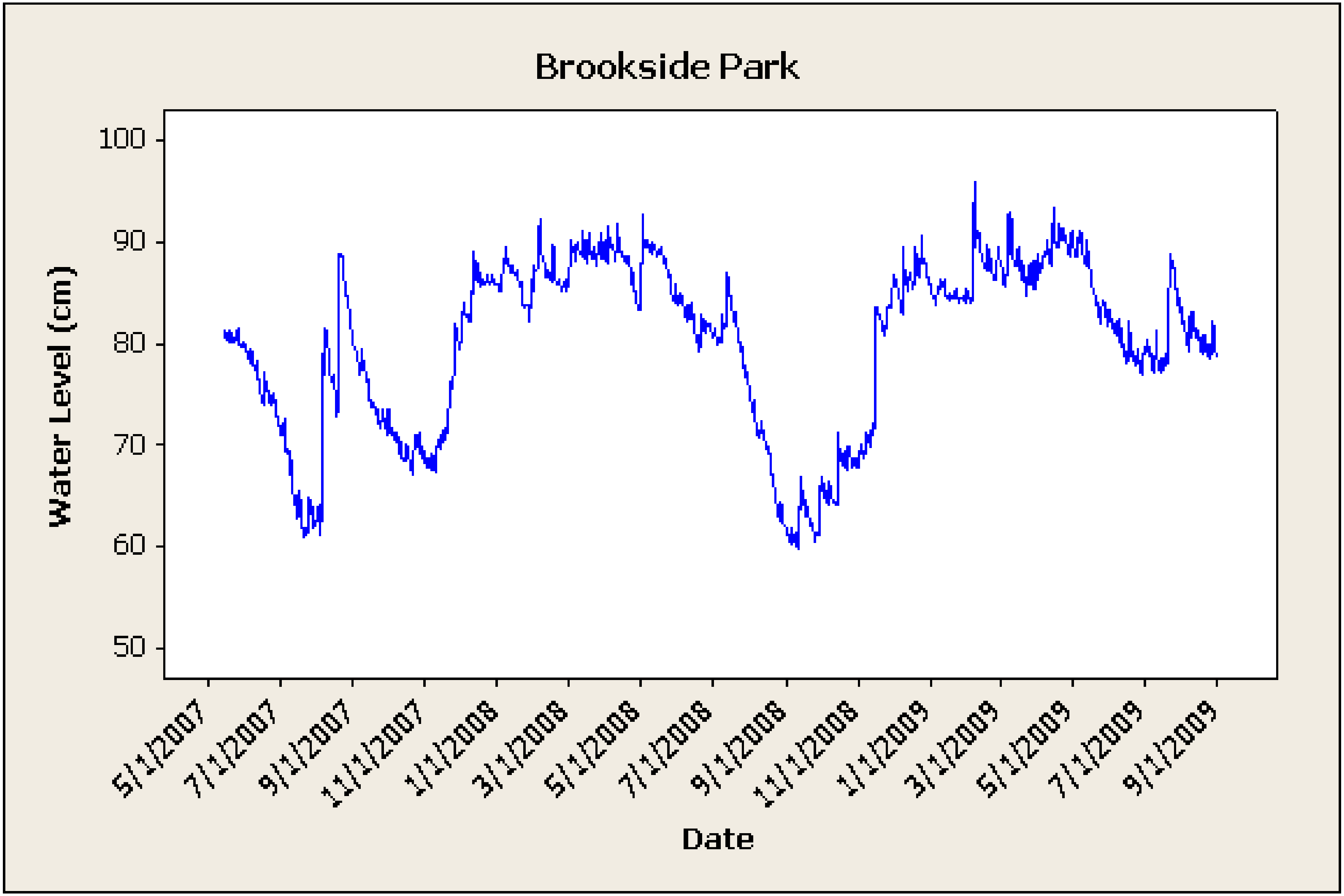

Figure 46. Brookside Park mitigation site (Cuyahoga County, Ohio) hydrograph, developed from monitoring well data.

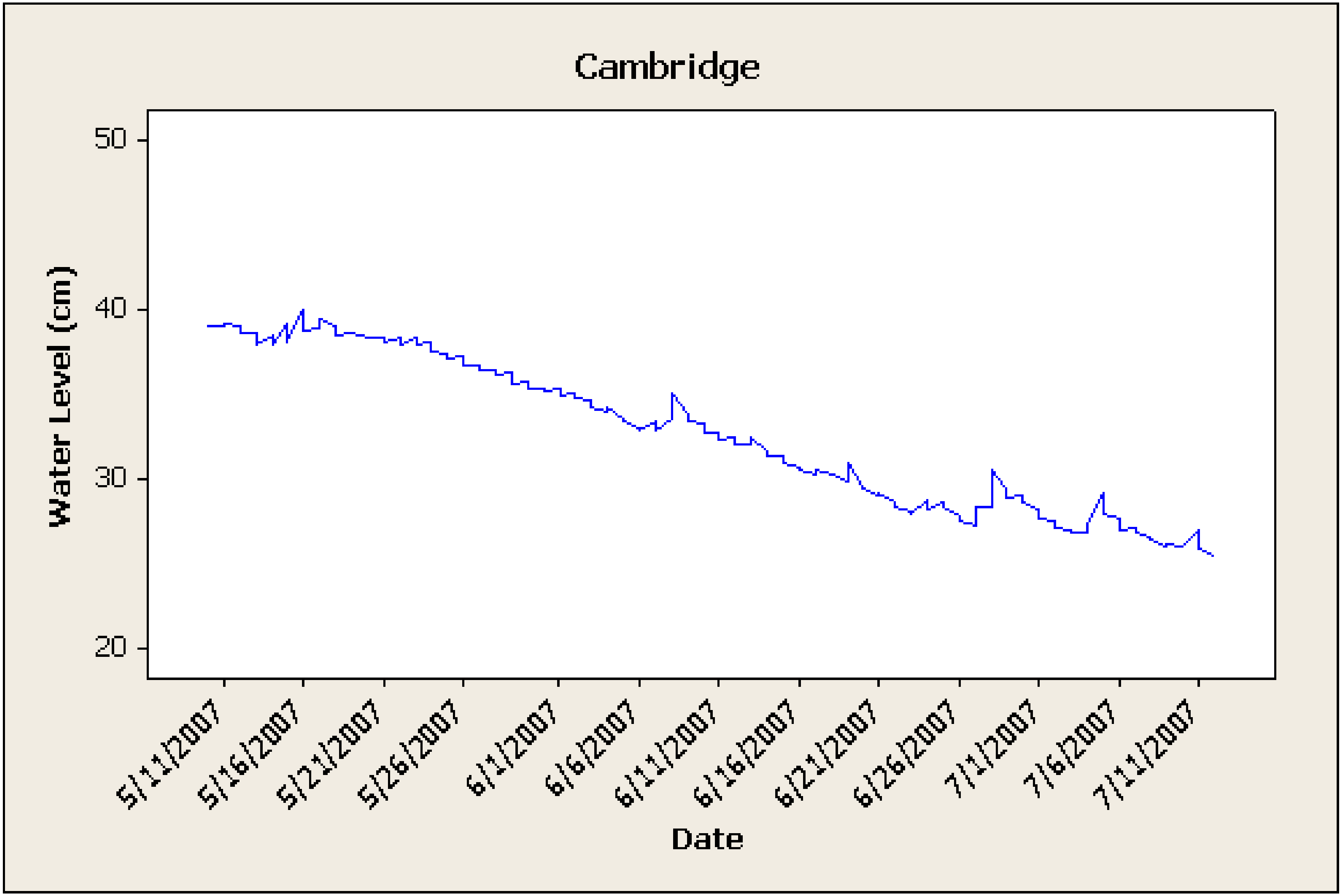

Figure 47. Cambridge mitigation site (Guernsey County, Ohio) hydrograph, developed from monitoring well data.

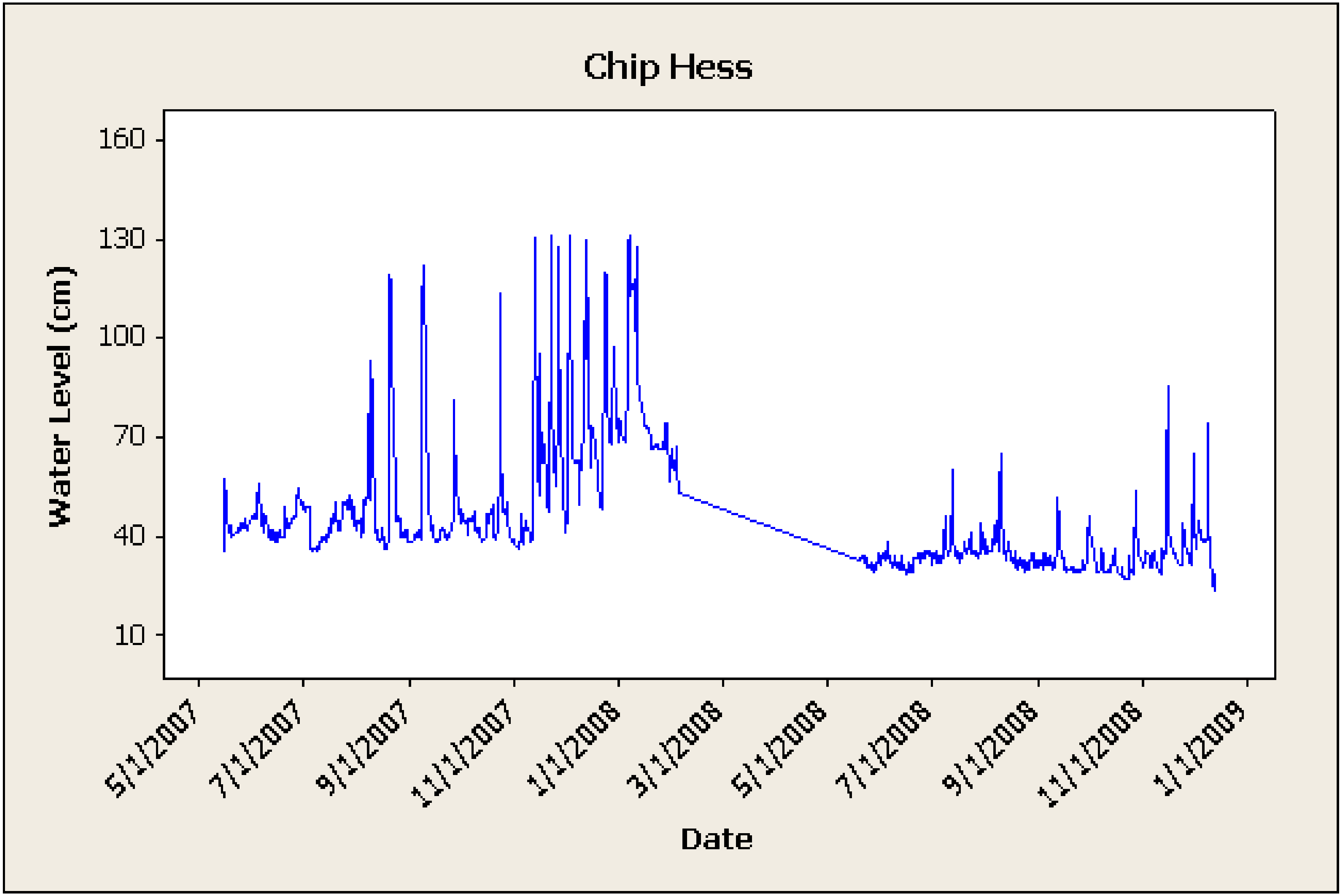

Figure 48. Chip Hess mitigation site (Geauga County, Ohio) hydrograph, developed from monitoring well data.

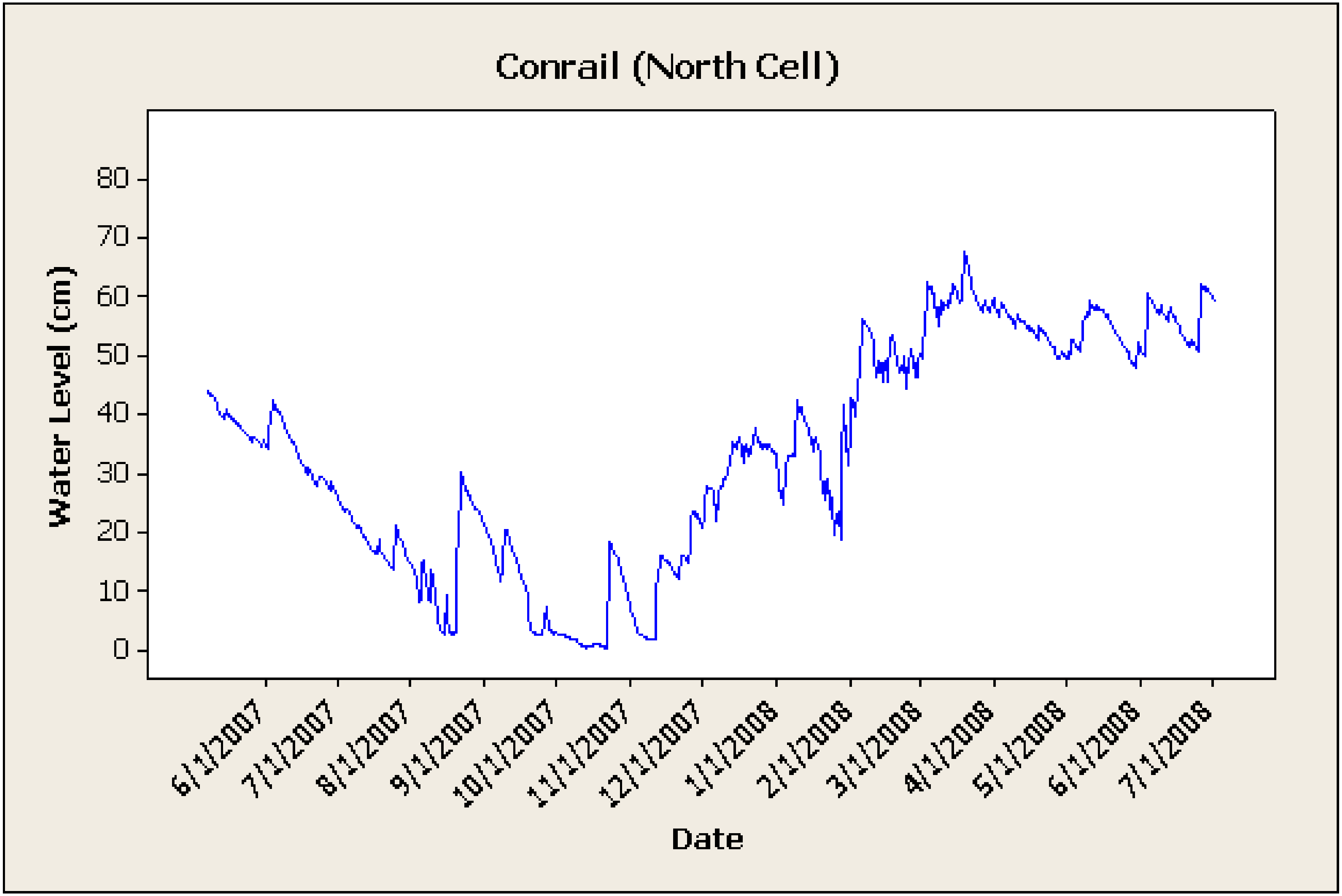

Figure 49. Conrail north cell mitigation site (Logan County, Ohio) hydrograph, developed from monitoring well data.

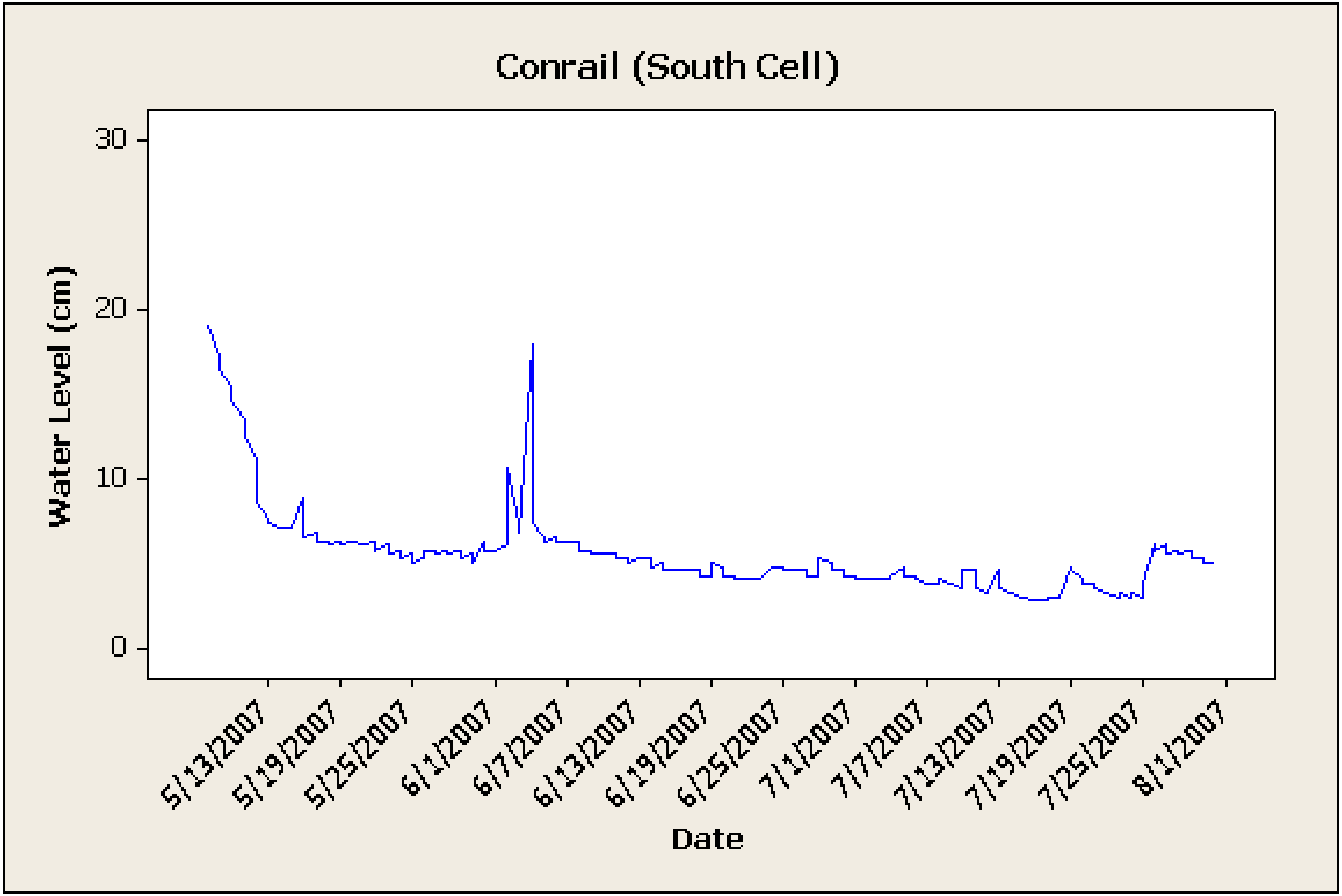

Figure 50. Conrail south cell mitigation site (Logan County, Ohio) hydrograph, developed from monitoring well data.

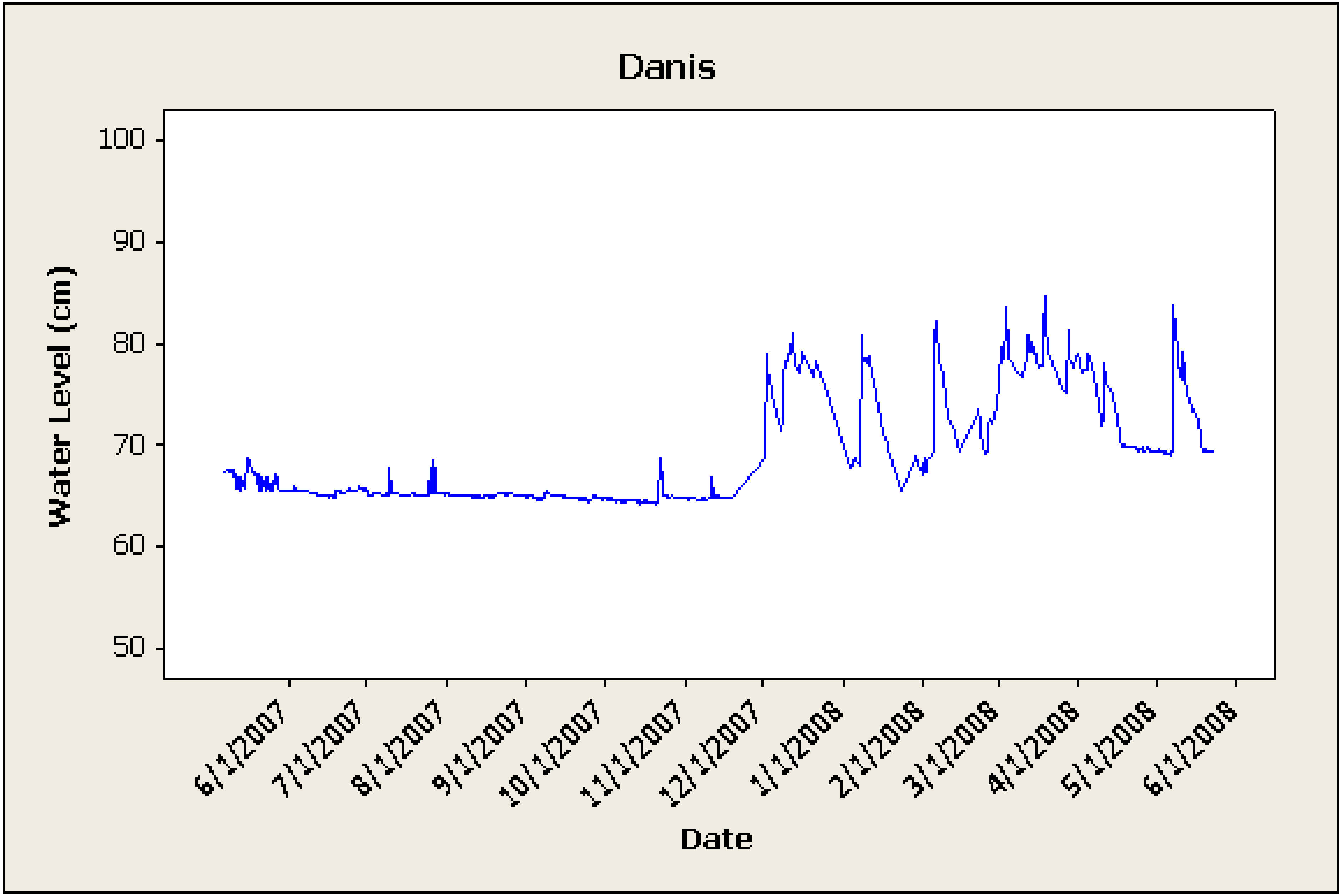

Figure 51. Danis mitigation site (Clark County, Ohio) hydrograph, developed from monitoring well data.

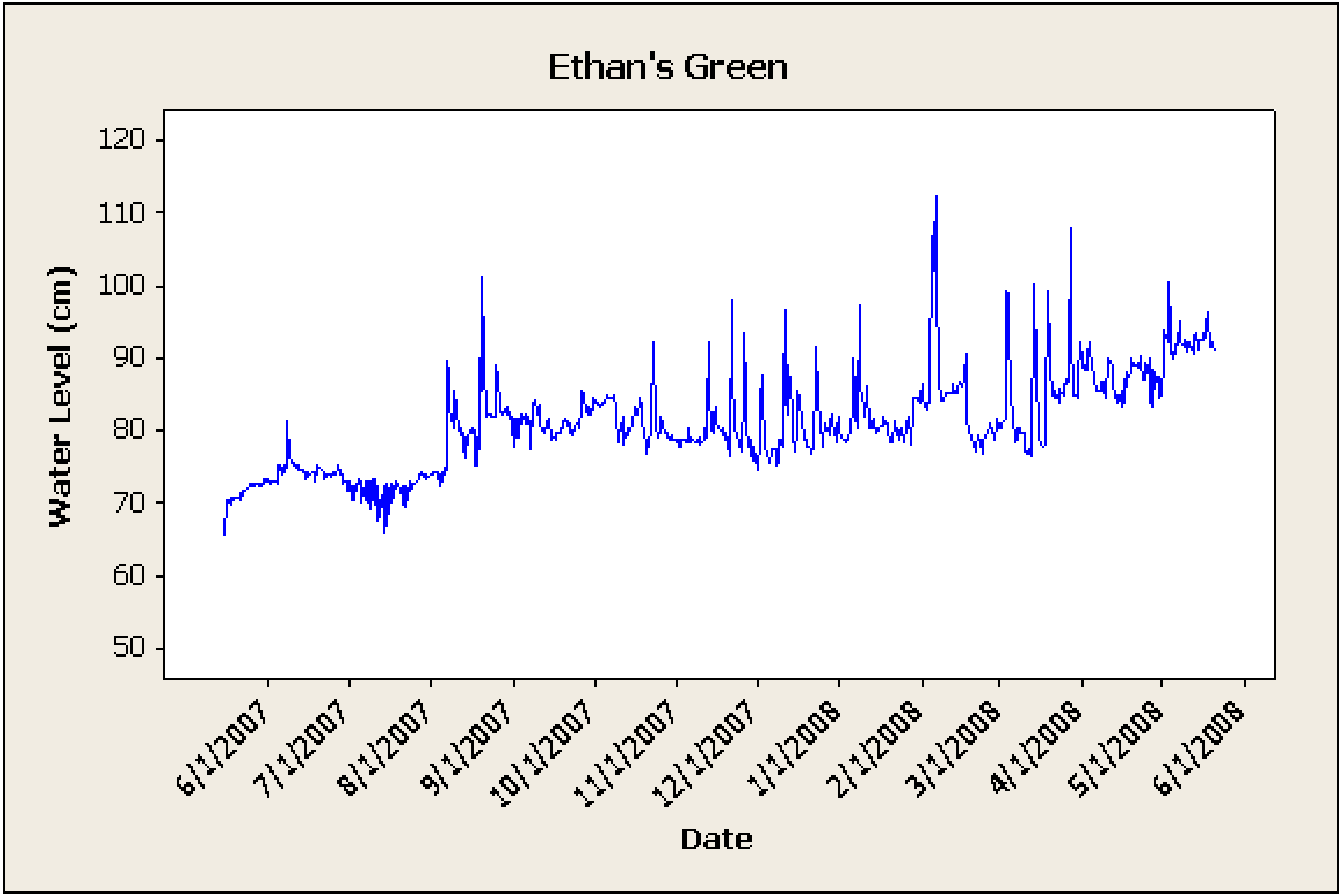

Figure 52. Ethan's Green mitigation site (Summit County, Ohio) hydrograph, developed from monitoring well data.

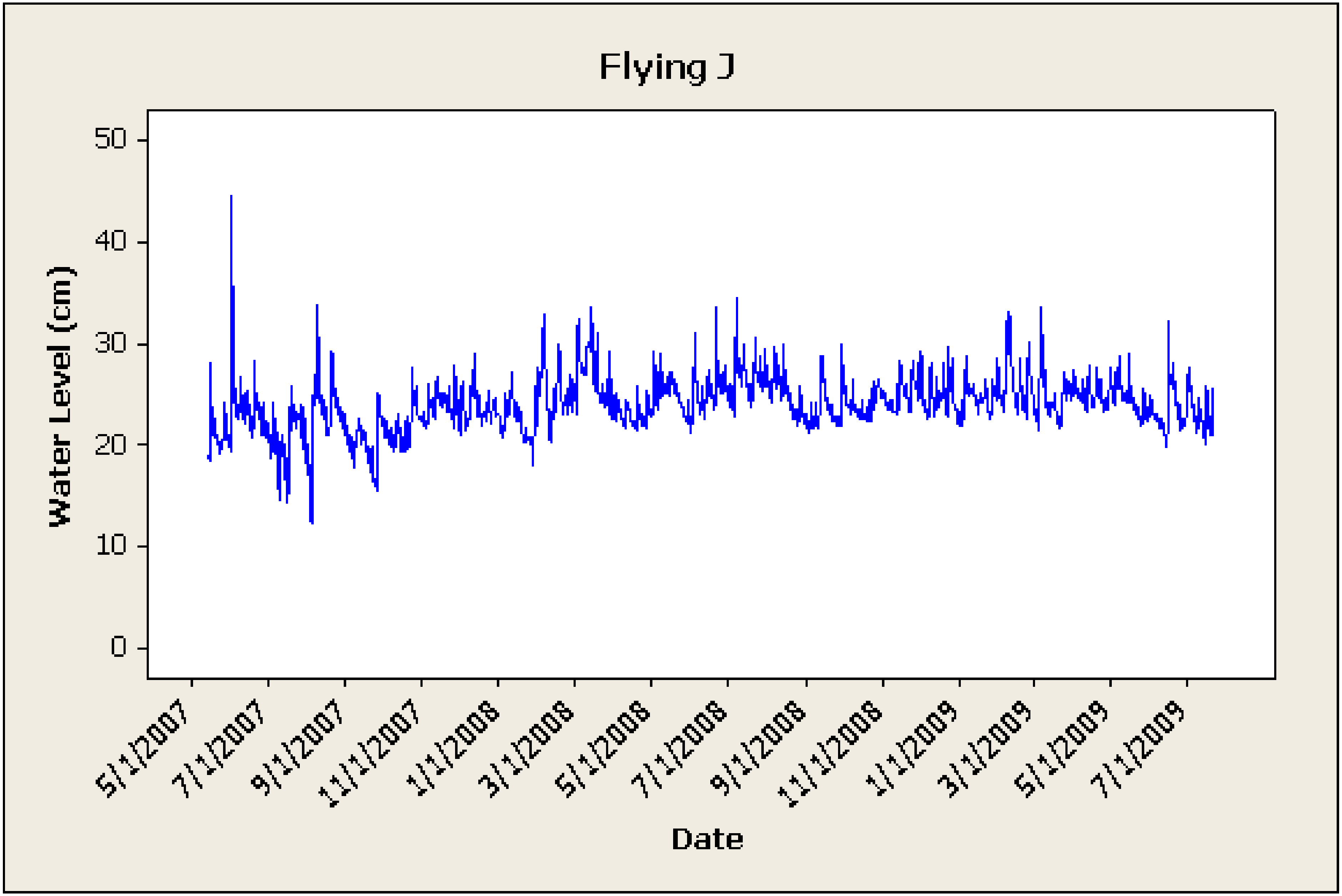

Figure 53. Flying J mitigation site (Trumbull County, Ohio) hydrograph, developed from monitoring well data.

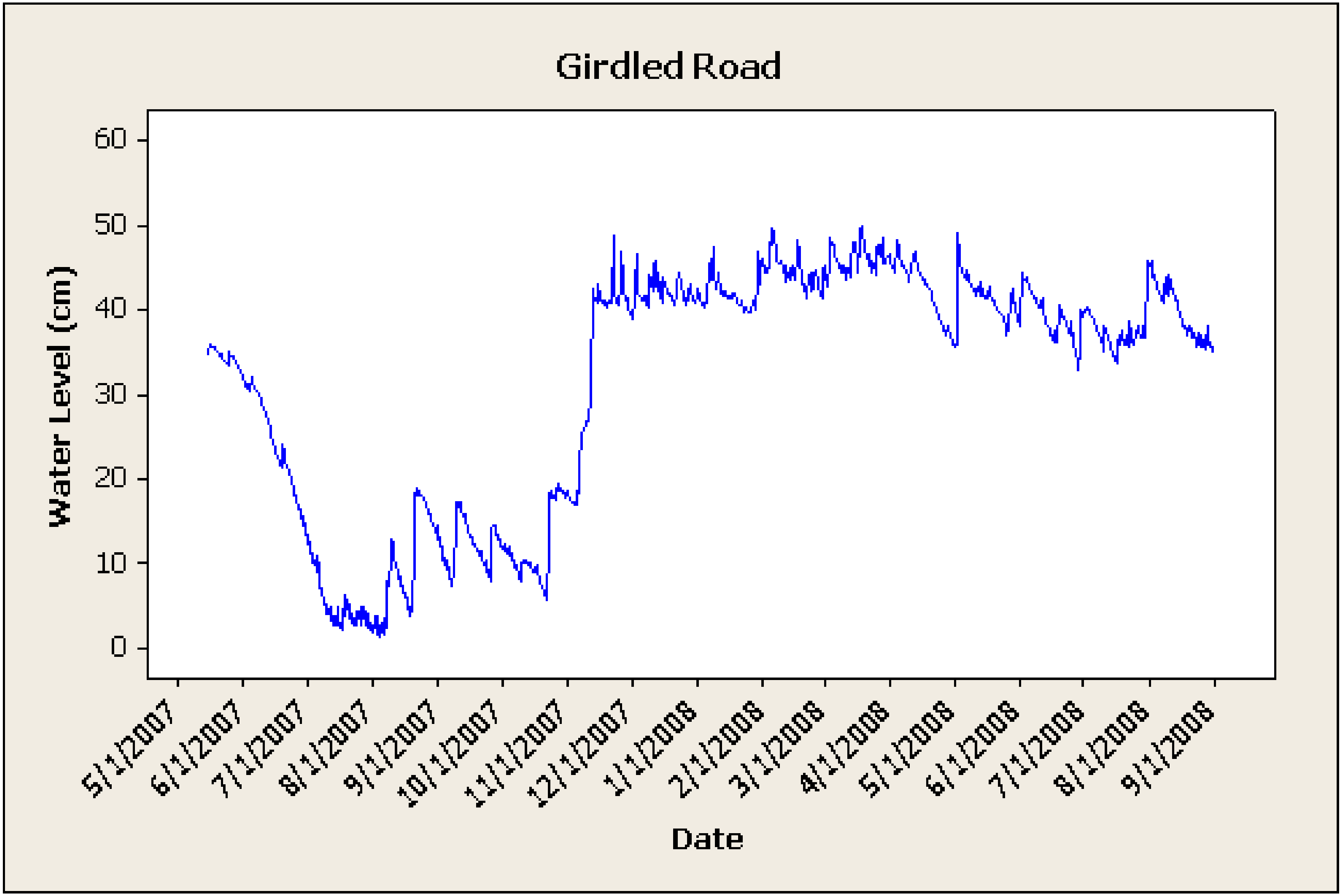

Figure 54. Girdled Road mitigation site (Lake County, Ohio) hydrograph, developed from monitoring well data.

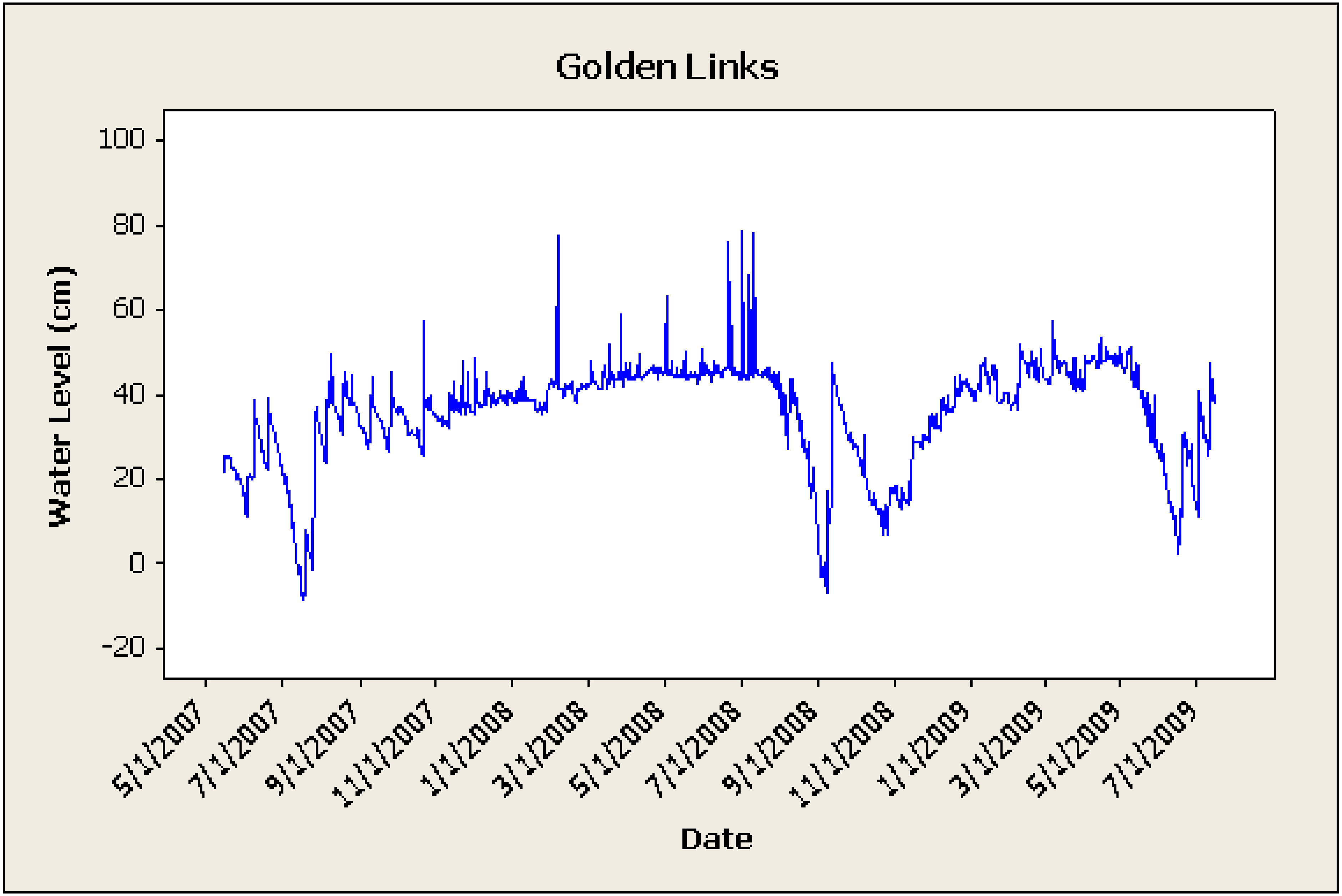

Figure 55. Golden Links mitigation site (Summit County, Ohio) hydrograph, developed from monitoring well data.

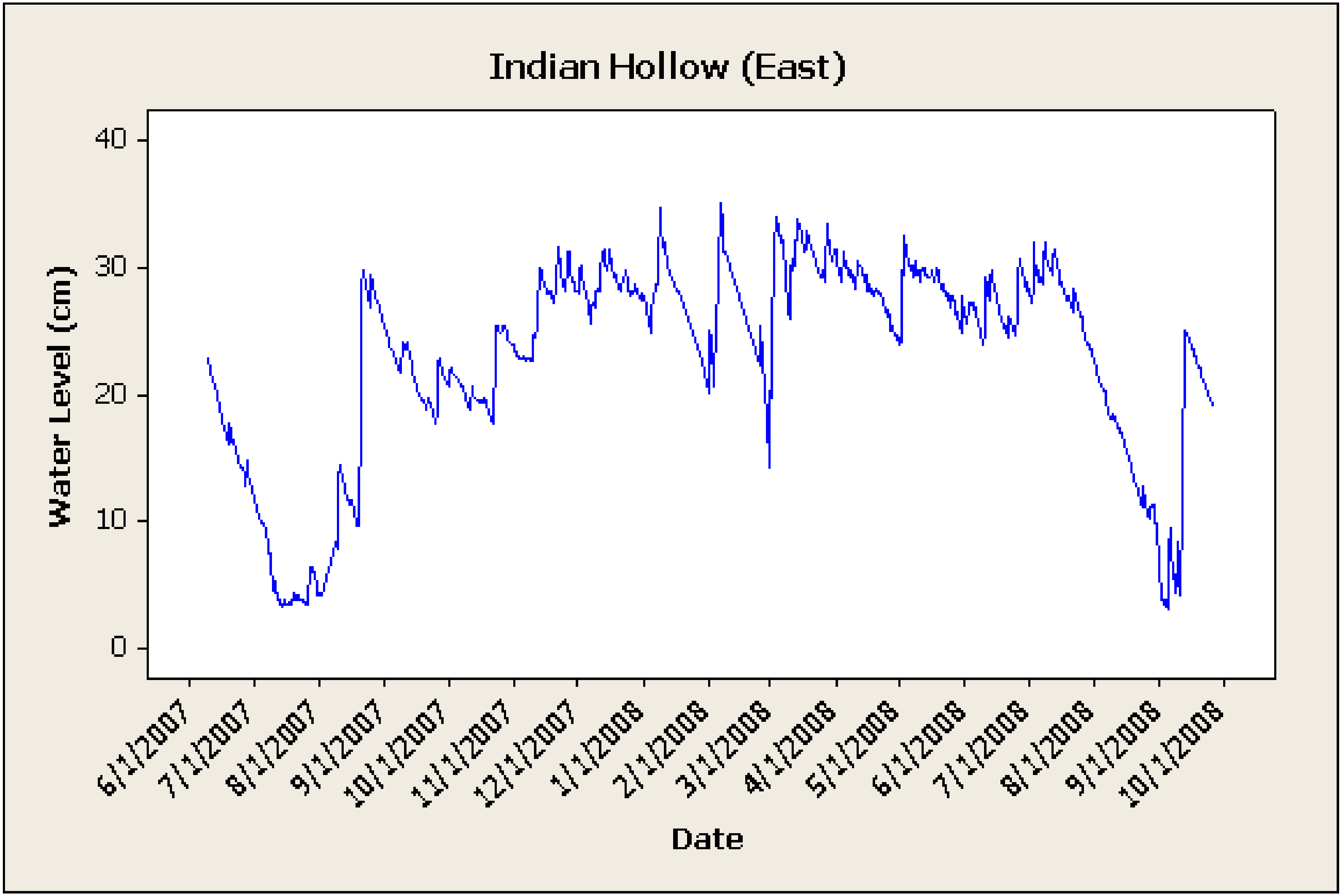

Figure 56. Indian Hollow east mitigation site (Lorain County, Ohio) hydrograph, developed from monitoring well data.

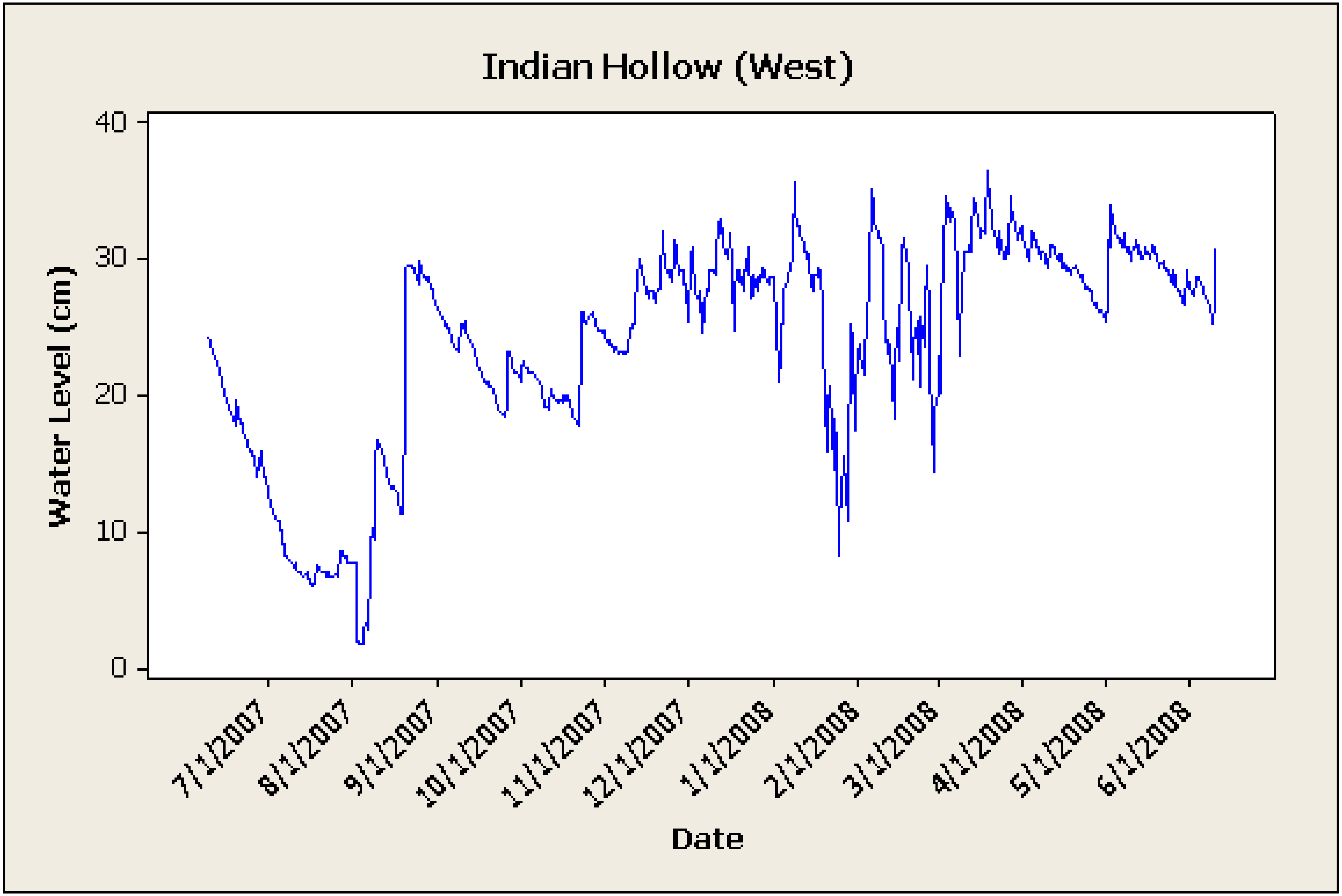

Figure 57. Indian Hollow west mitigation site (Lorain County, Ohio) hydrograph, developed from monitoring well data.

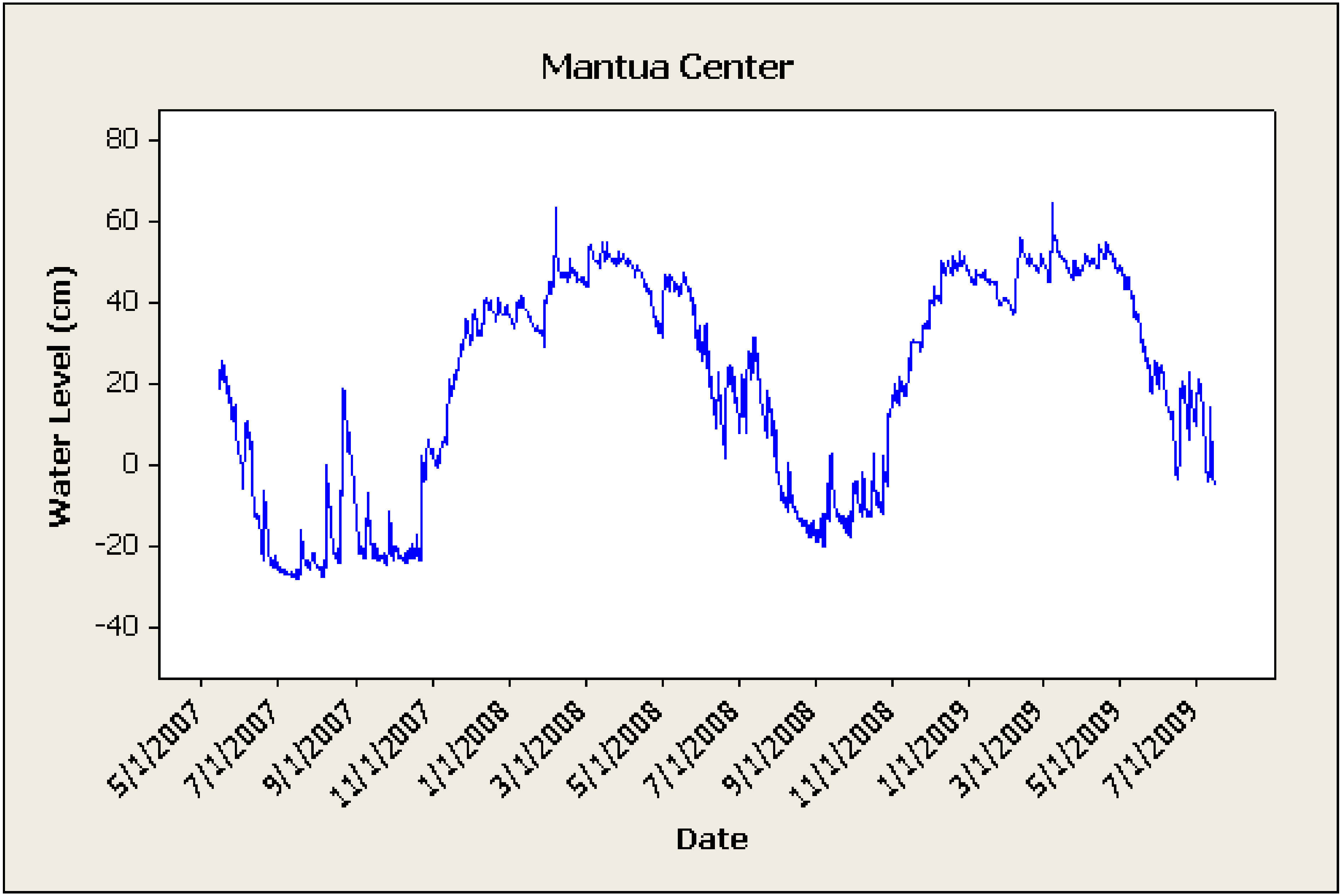

Figure 58. Mantua Center mitigation site (Portage County, Ohio) hydrograph, developed from monitoring well data.

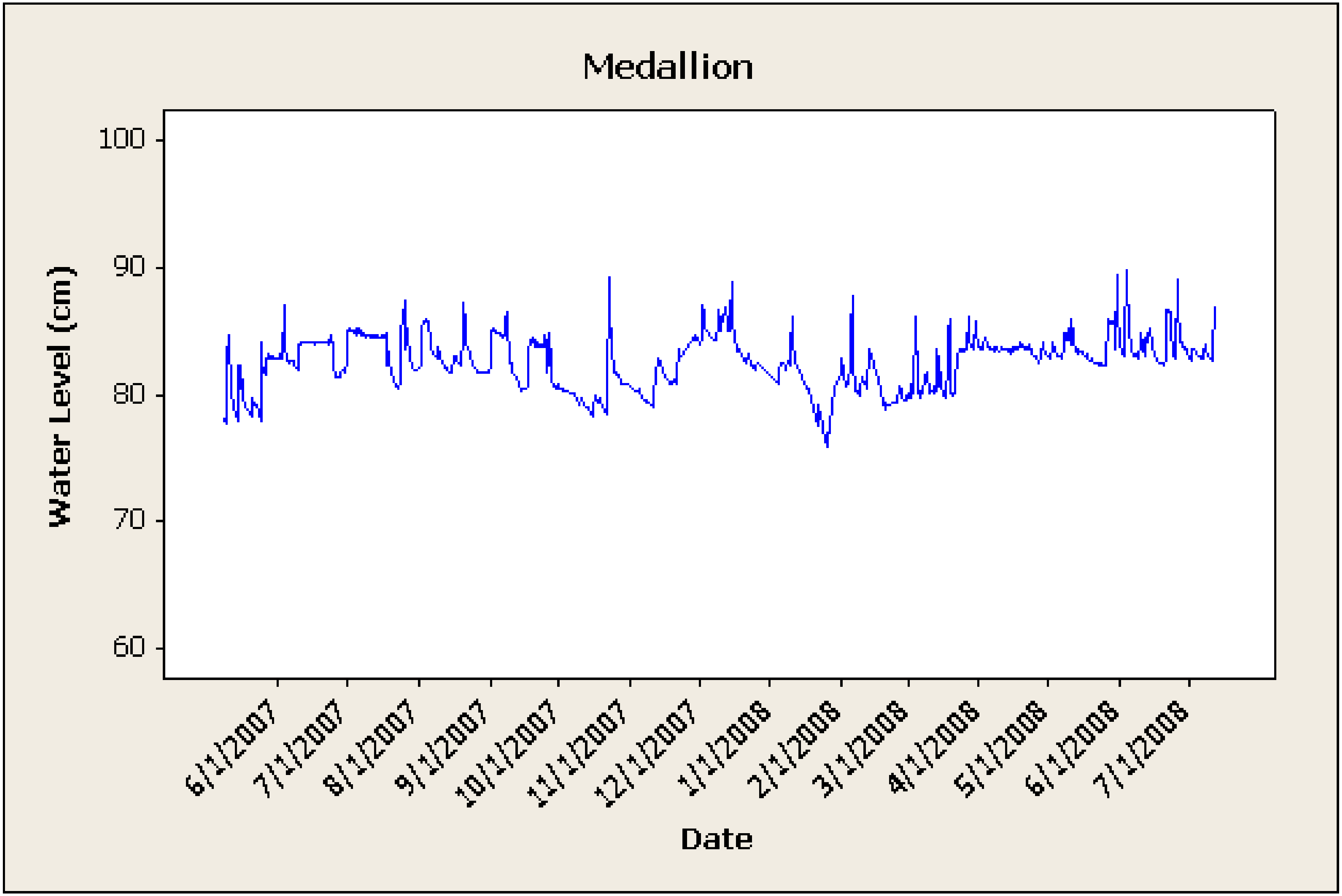

Figure 59. Medallion mitigation site (Delaware County, Ohio) hydrograph, developed from monitoring well data.

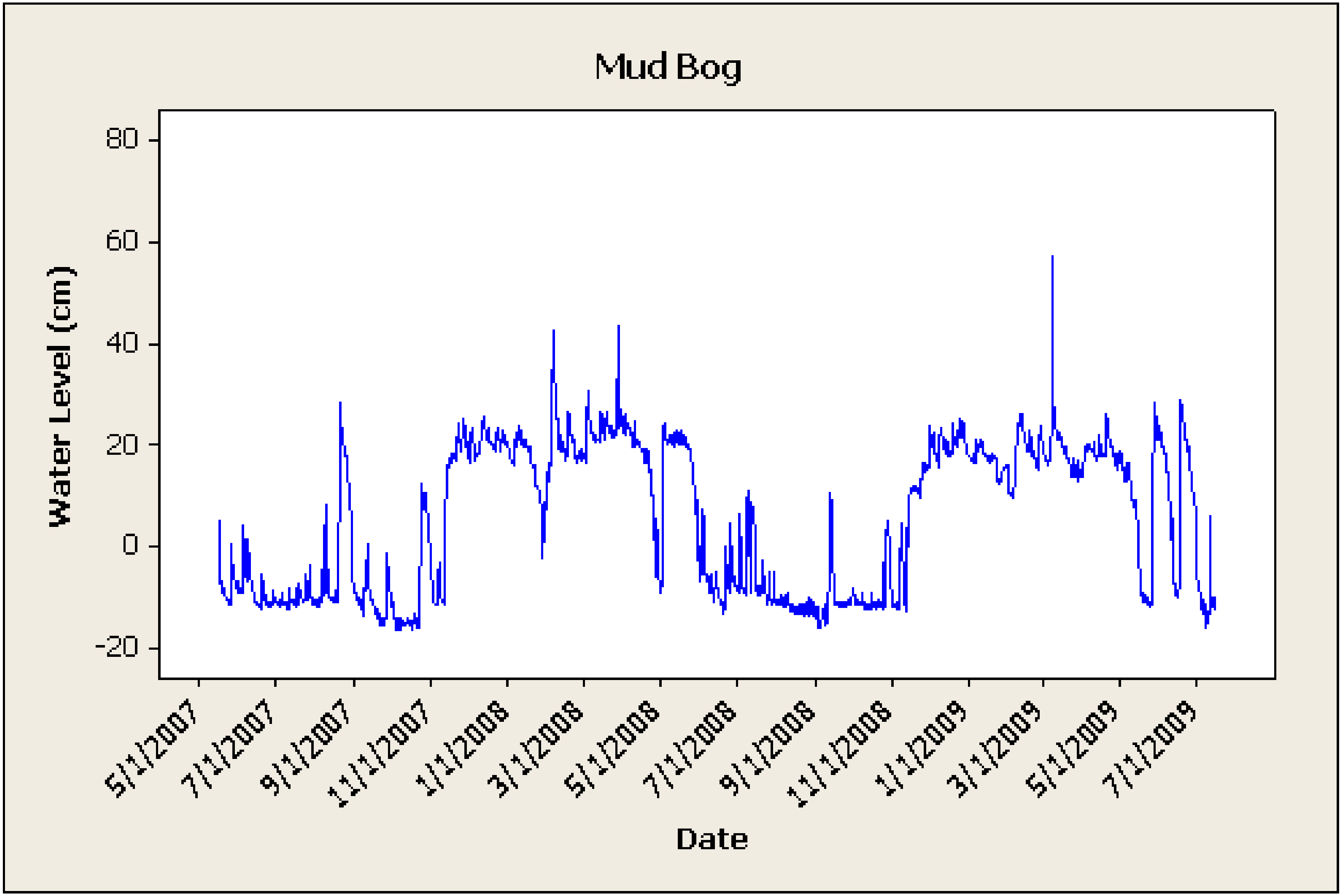

Figure 60. Mud Bog mitigation site (Summit County, Ohio) hydrograph, developed from monitoring well data.

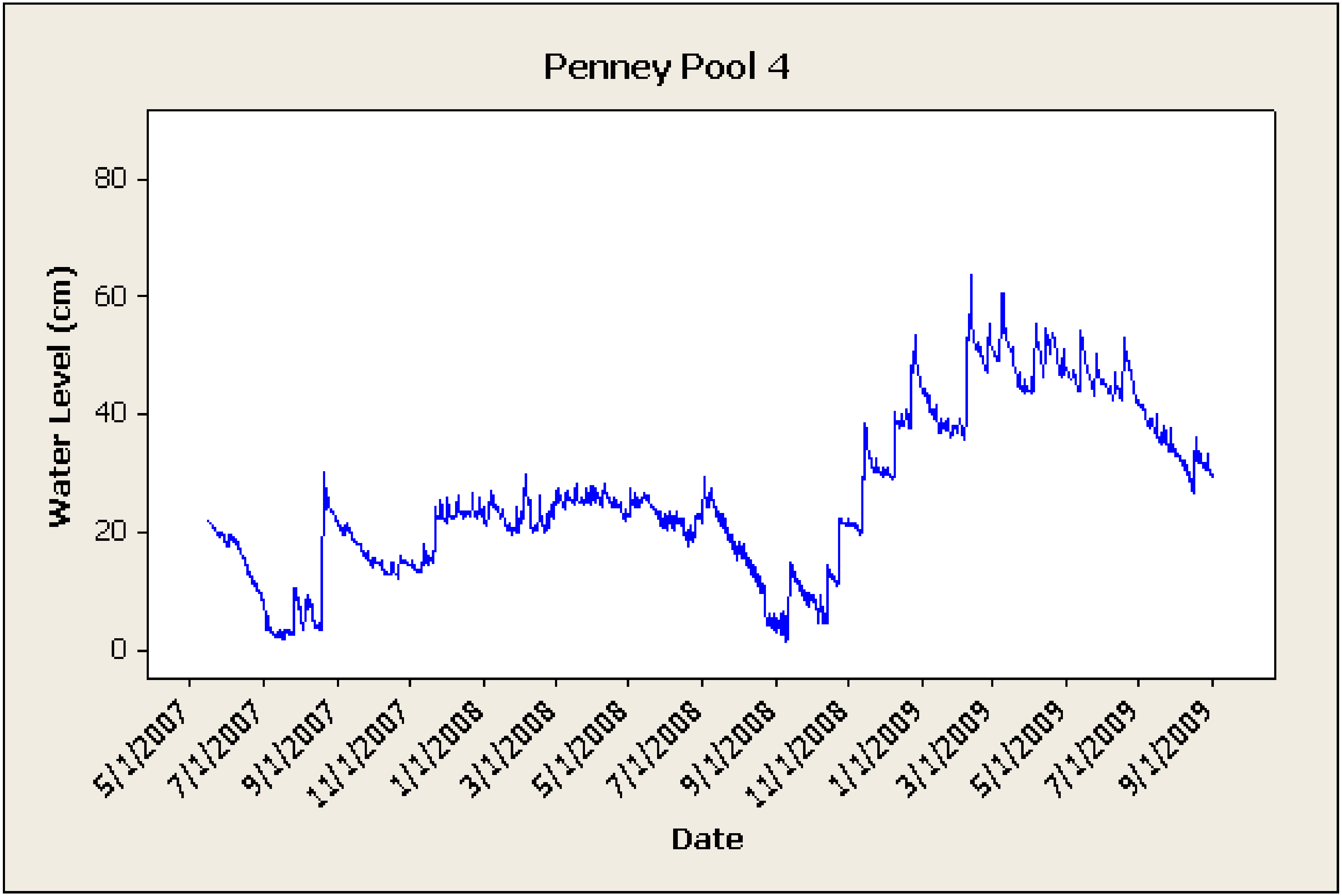

Figure 61. Penney Pool 4 mitigation site (Defiance County, Ohio) hydrograph, developed from monitoring well data.

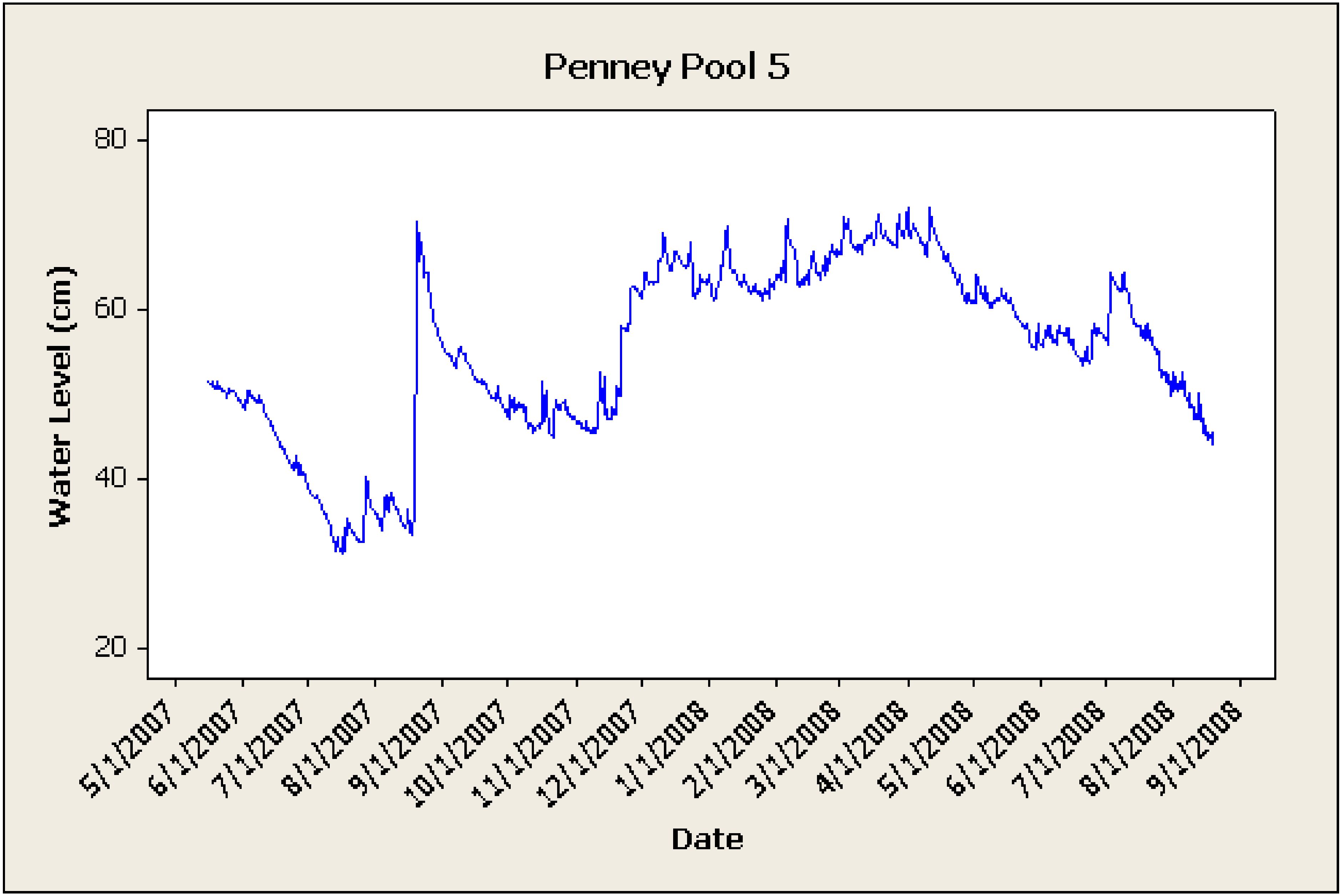

Figure 62. Penney Pool 5 mitigation site (Defiance County, Ohio) hydrograph, developed from monitoring well data.

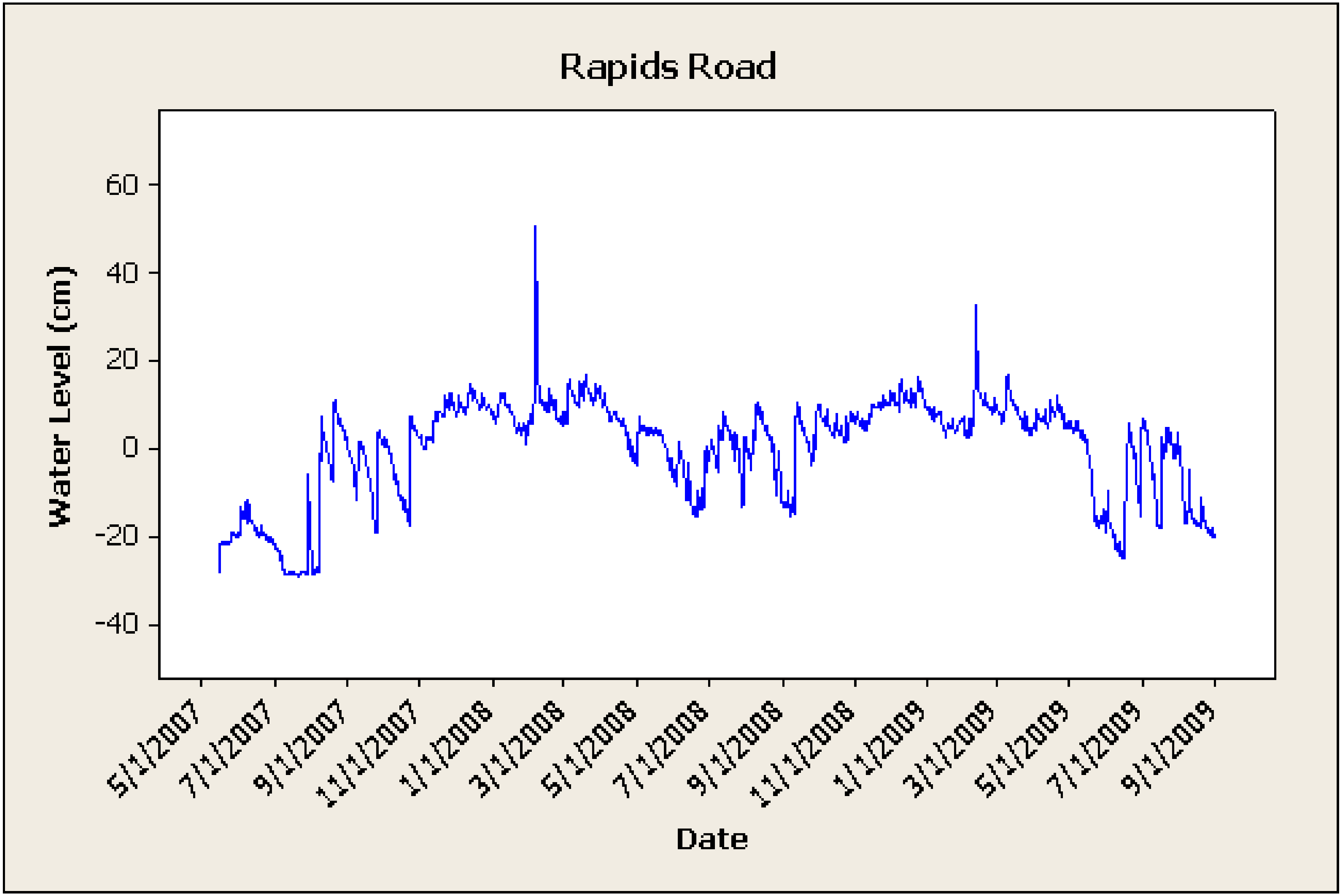

Figure 63. Rapids Road mitigation site (Geauga County, Ohio) hydrograph, developed from monitoring well data.

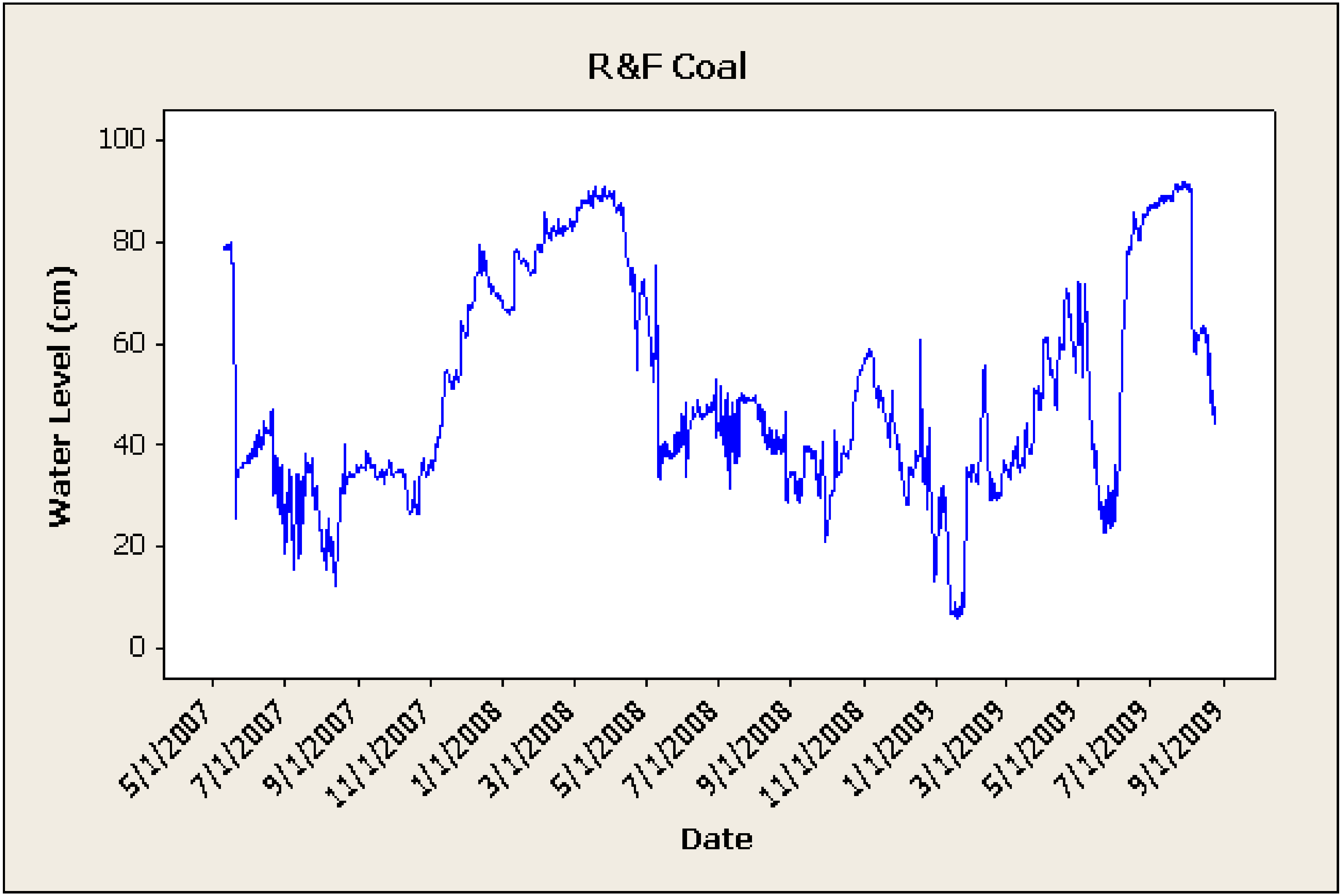

Figure 64. R&F Coal mitigation site (Belmont County, Ohio) hydrograph, developed from monitoring well data.

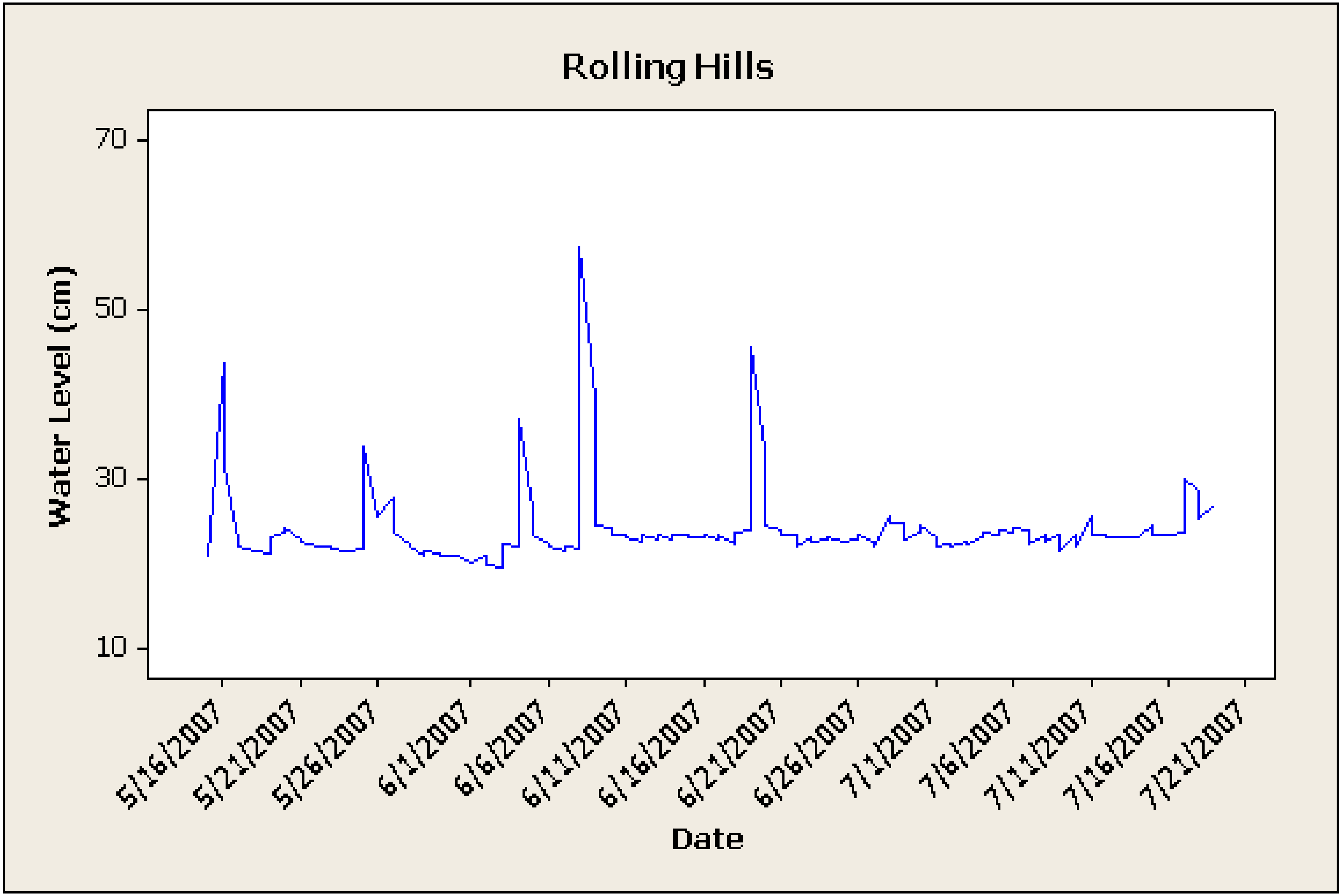

Figure 65. Rolling Hills mitigation site (Summit County, Ohio) hydrograph, developed from monitoring well data.

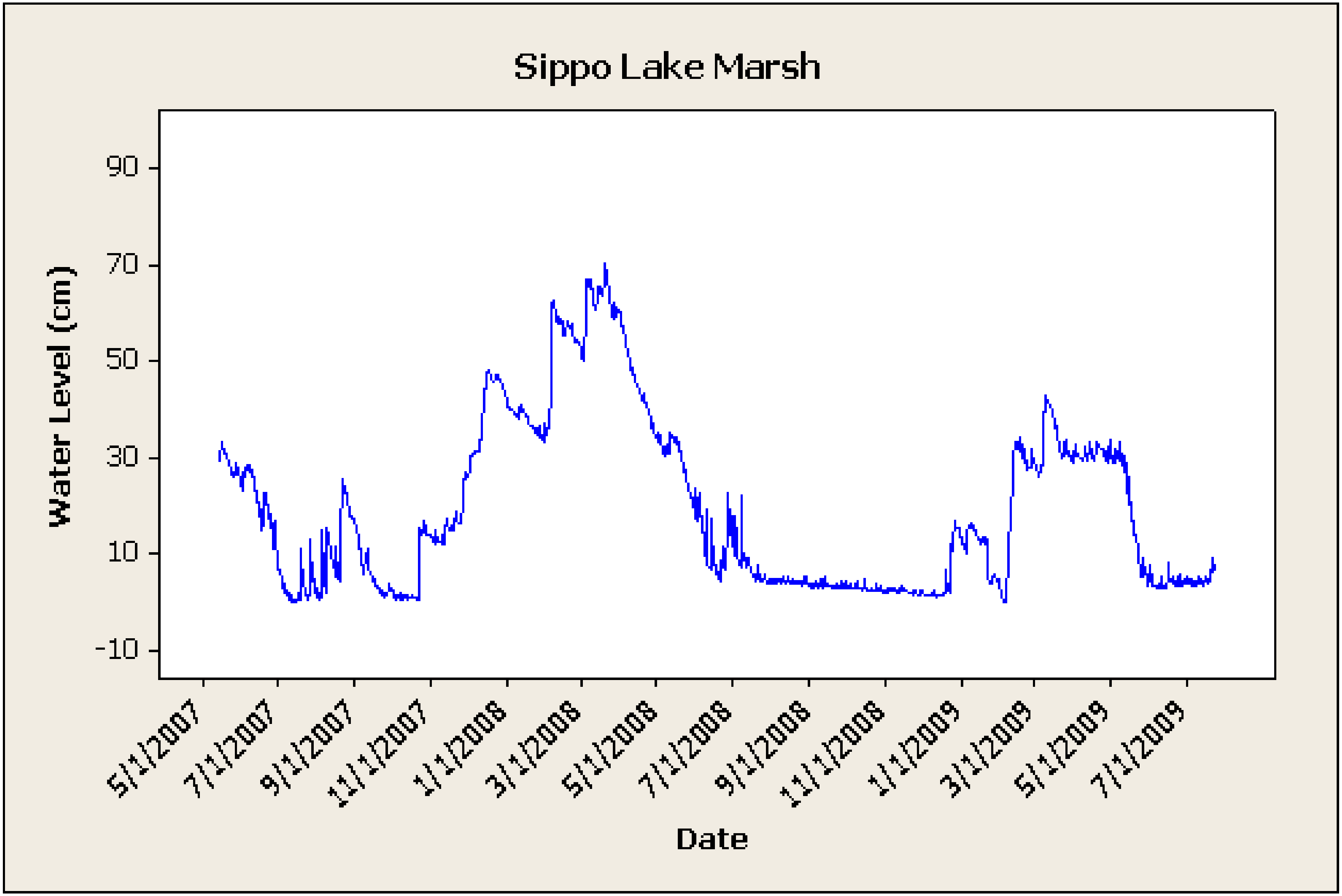

Figure 66. Sippo Lake Marsh mitigation site (Stark County, Ohio) hydrograph, developed from monitoring well data.

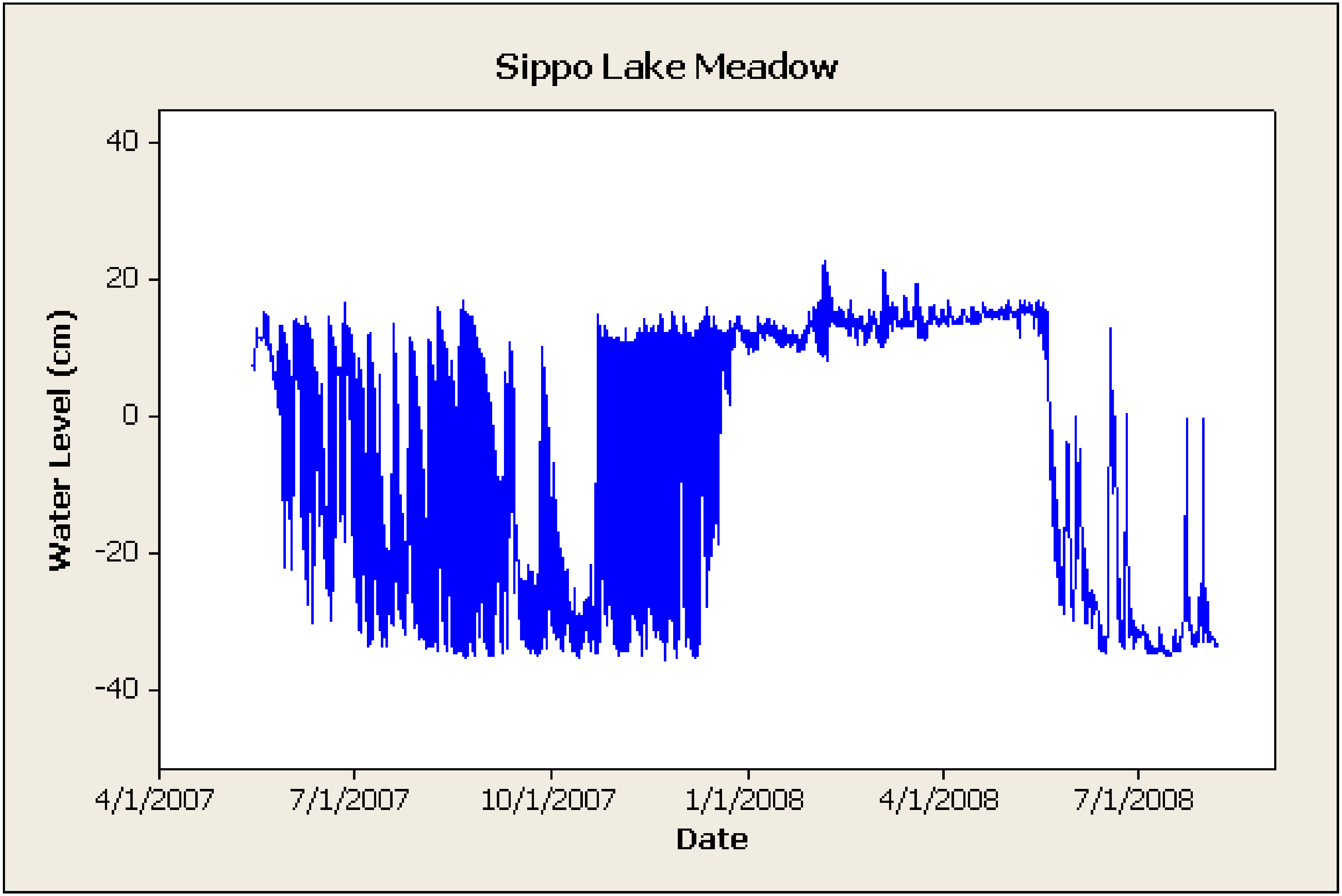

Figure 67. Sippo Lake Meadow mitigation site (Stark County, Ohio) hydrograph, developed from monitoring well data.

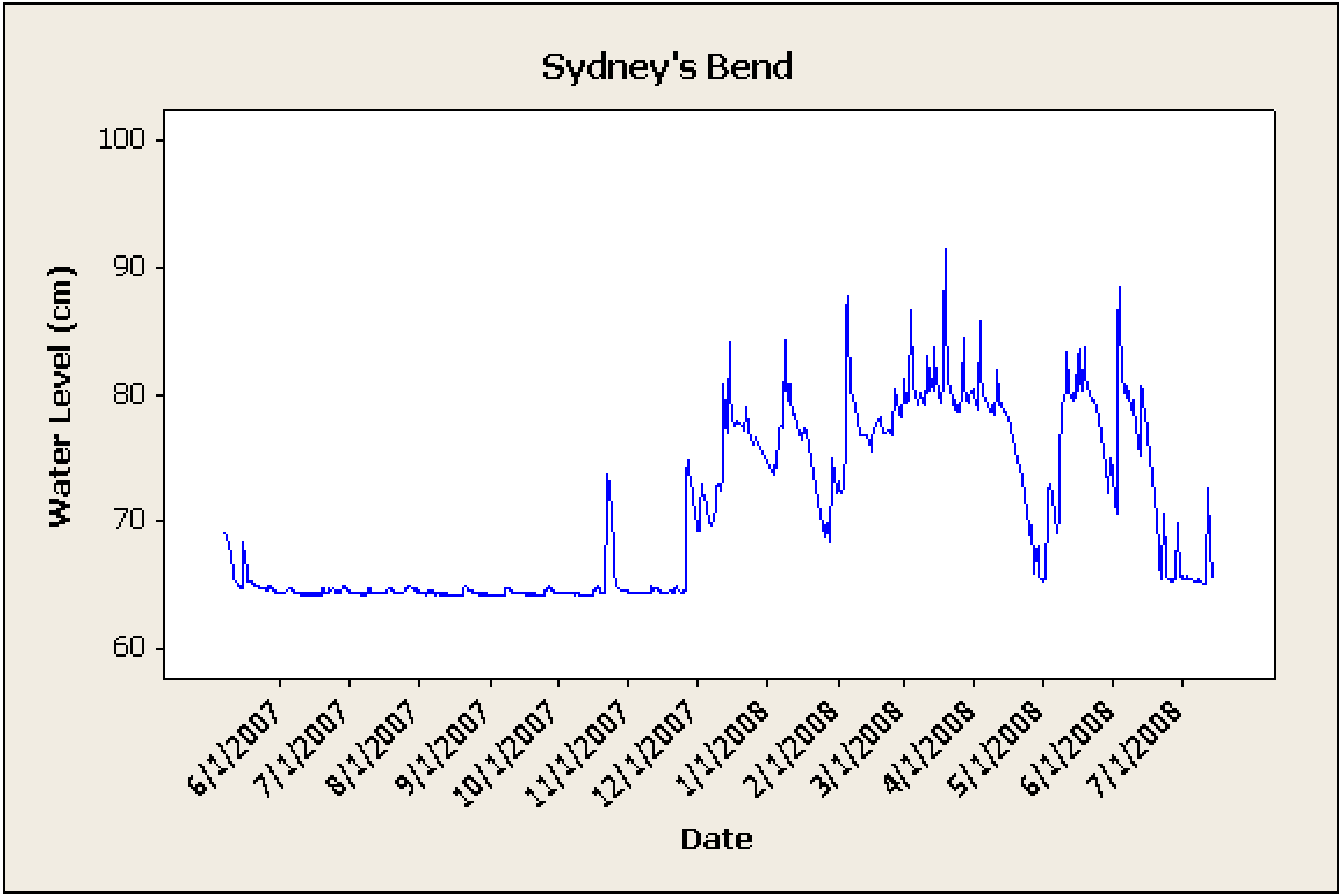

Figure 68. Sydney's Bend Meadow mitigation site (Montgomery County, Ohio) hydrograph, developed from monitoring well data.

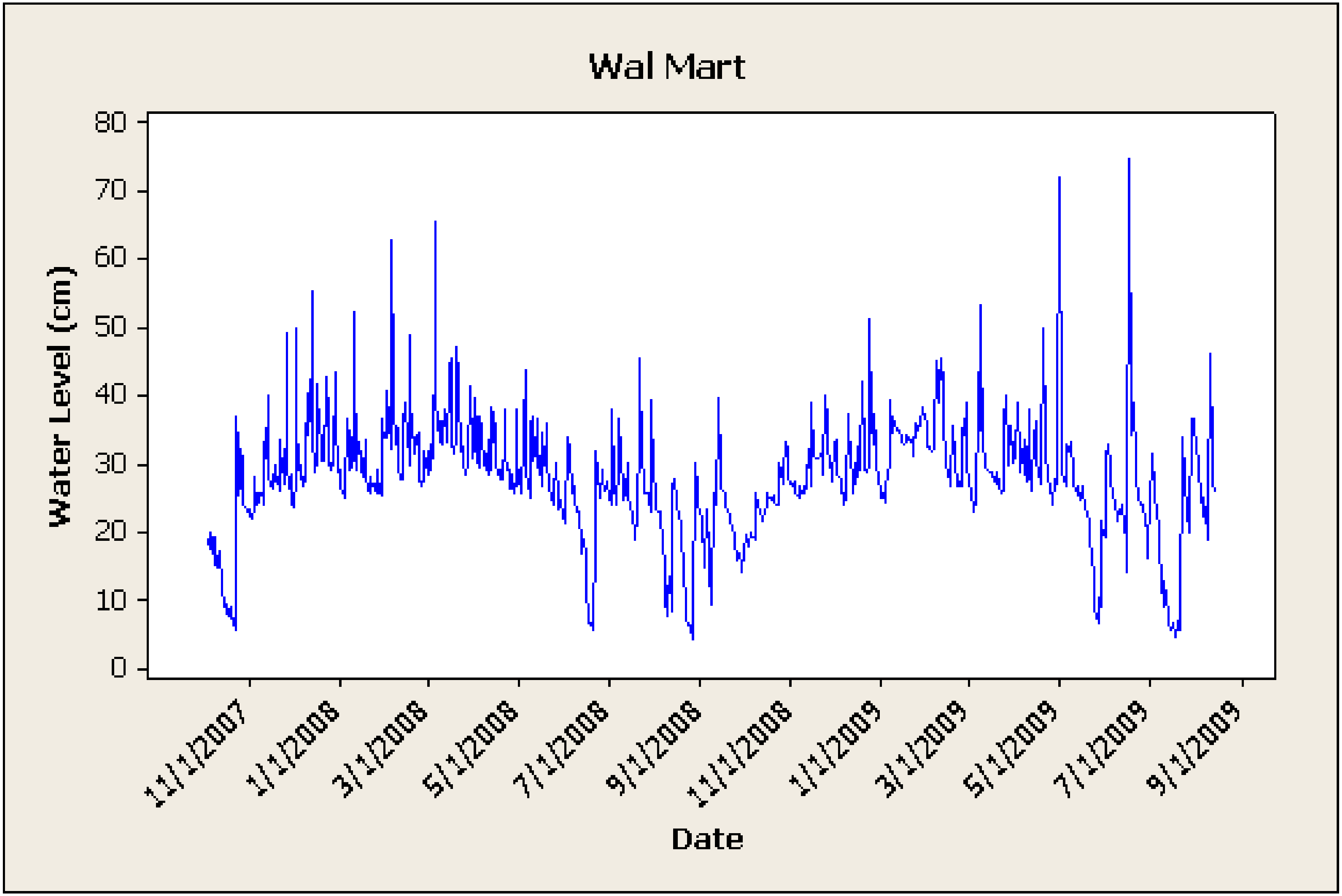

Figure 69. Wal Mart mitigation site (Mahoning County, Ohio) hydrograph, developed from monitoring well data.

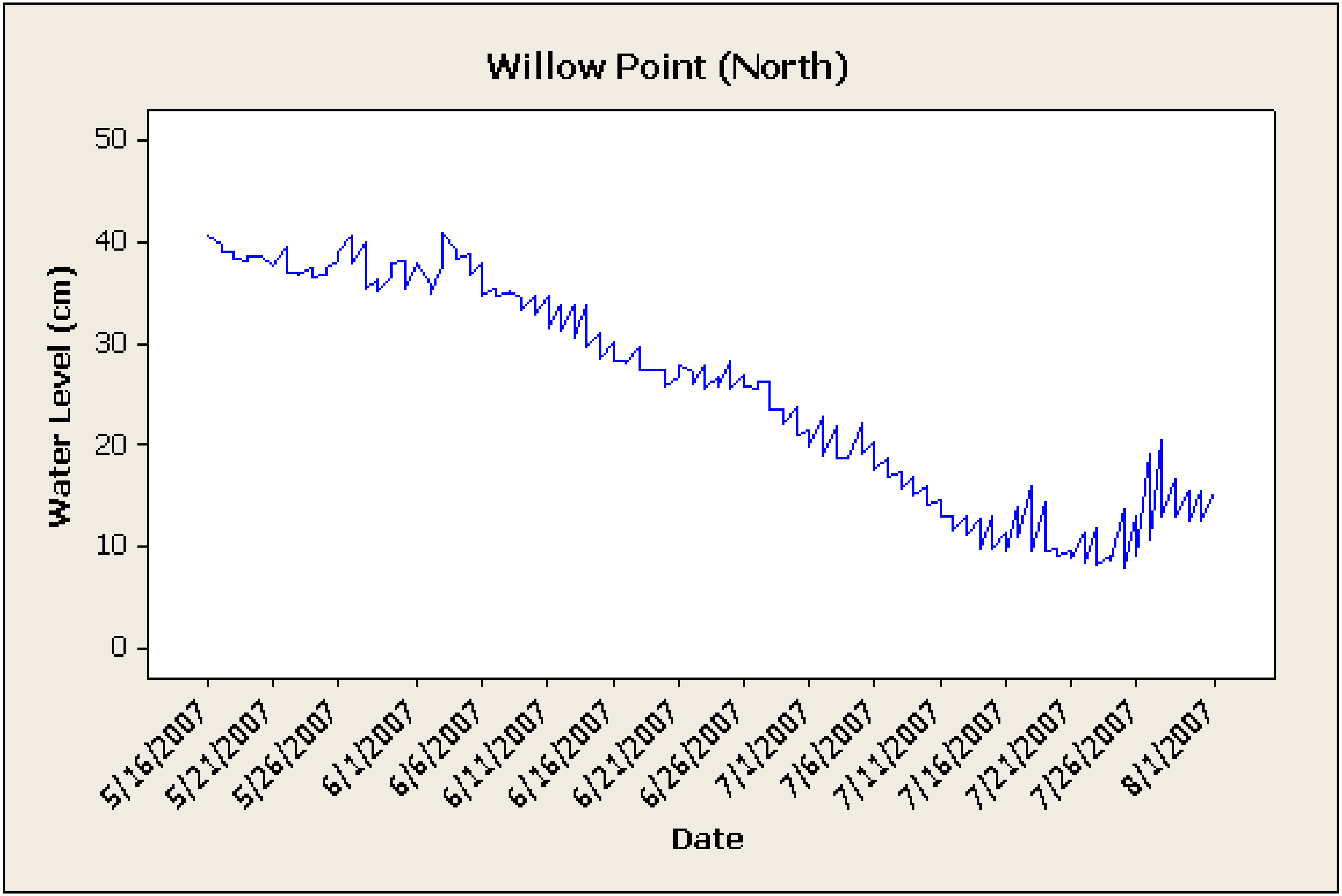

Figure 70. Willow Point north mitigation site (Erie County, Ohio) hydrograph, developed from monitoring well data.

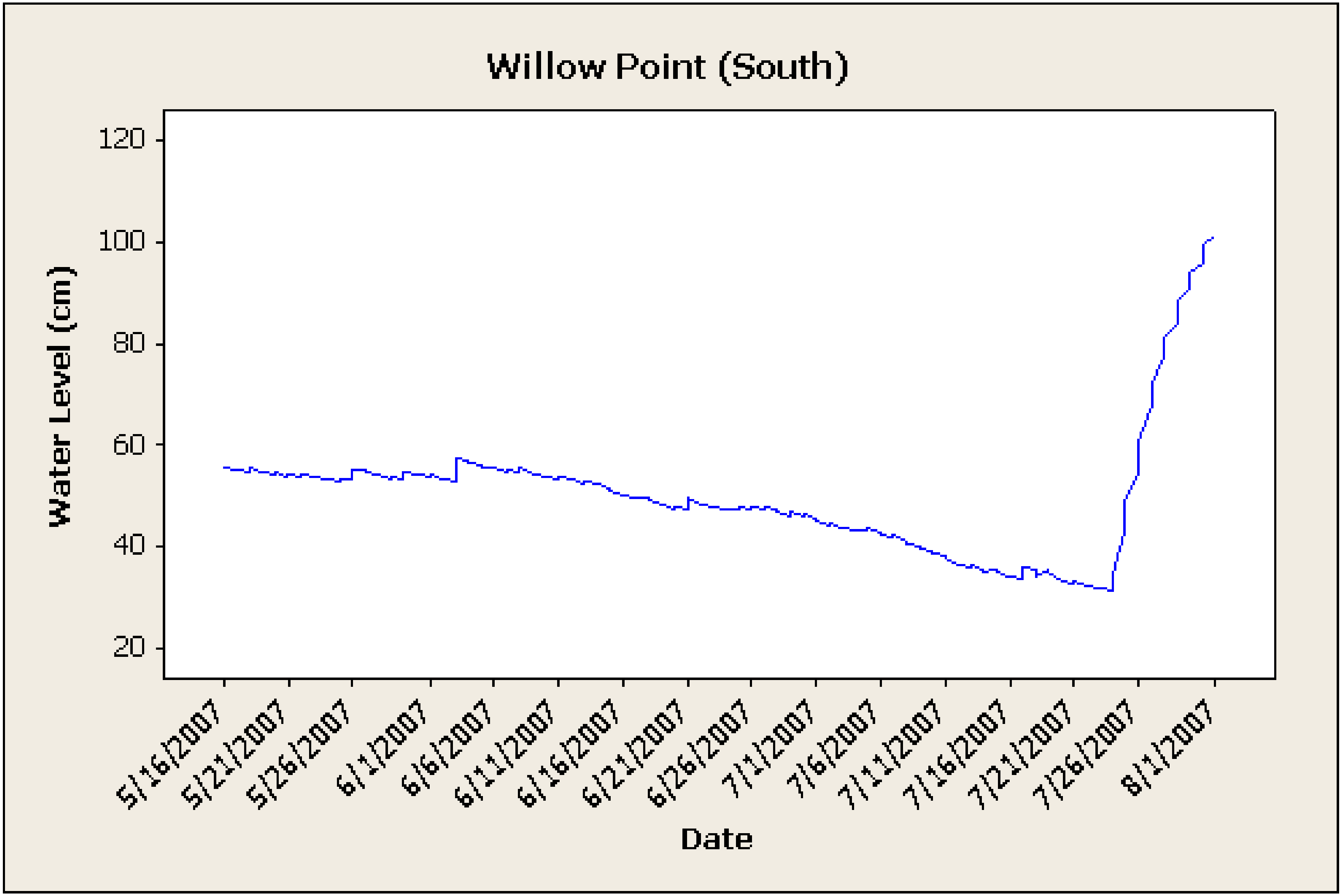

Figure 71. Willow Point south mitigation site (Erie County, Ohio) hydrograph, developed from monitoring well data.

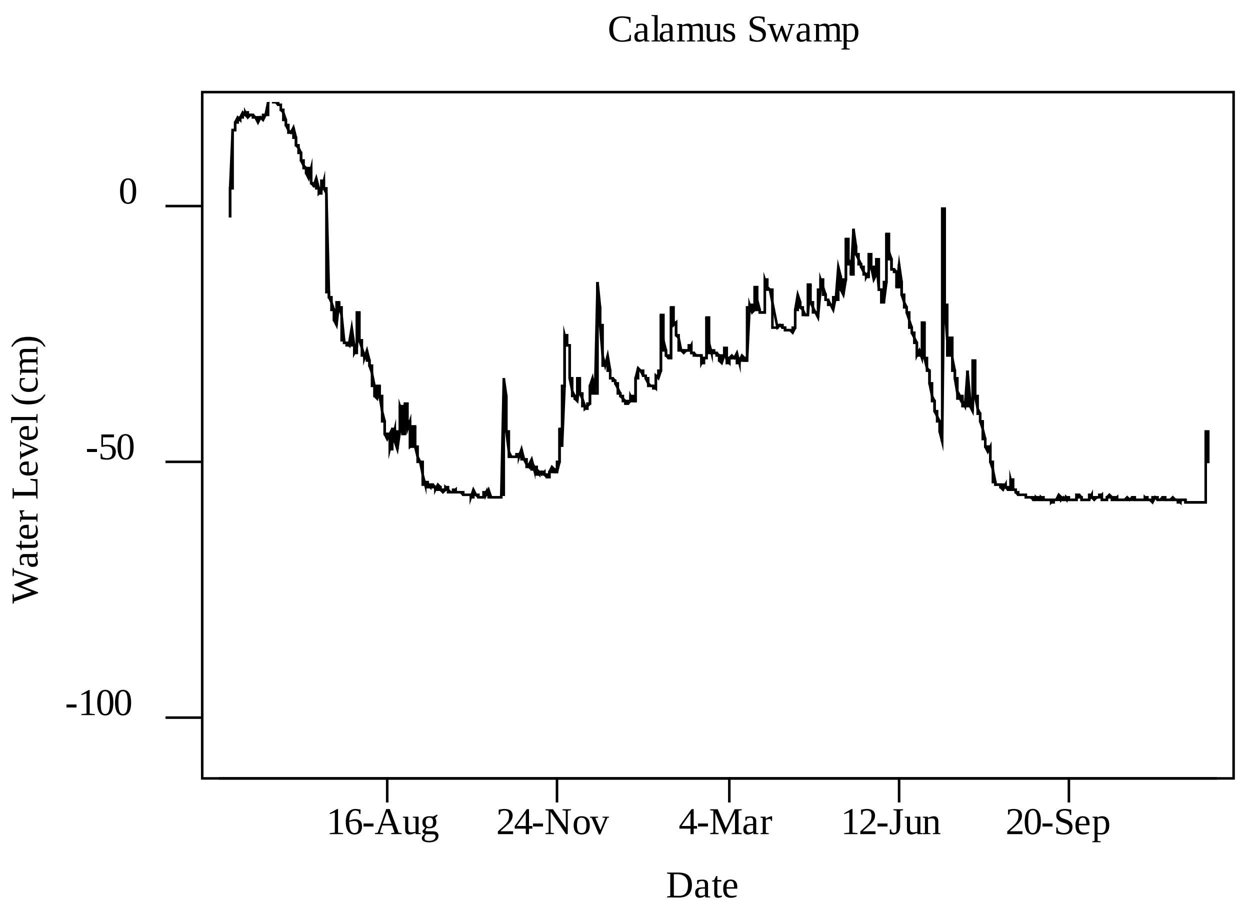

Figure 72. A natural depressional wetland (Calamus Swamp, Pickaway County, Ohio) hydrograph, developed from monitoring well data.

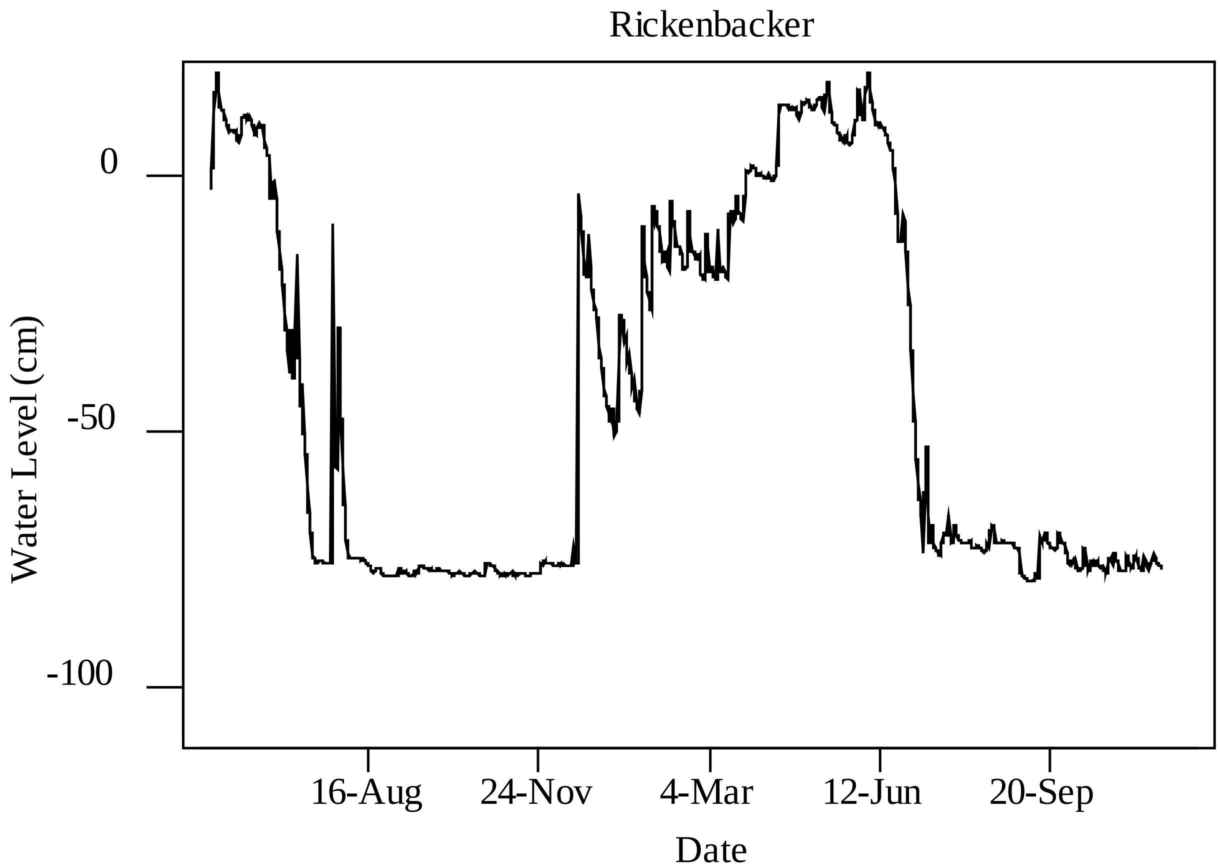

Figure 73. A natural depressional wetland (Rickenbacker, Franklin County, Ohio) hydrograph, developed from monitoring well data.

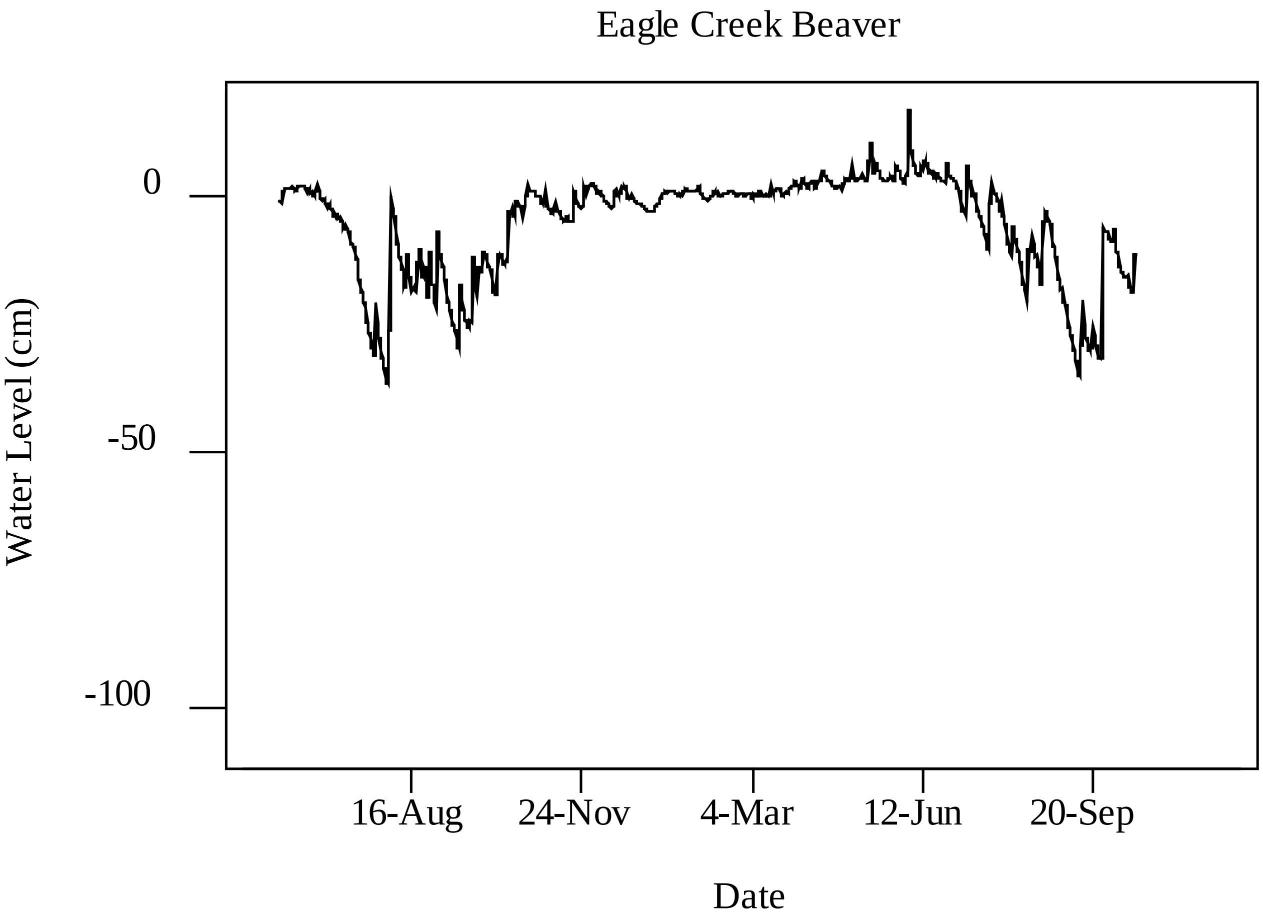

Figure 74. A natural riverine headwater depressional wetland (Eagle Creek Beaver, Portage County, Ohio) hydrograph, developed from monitoring well data.

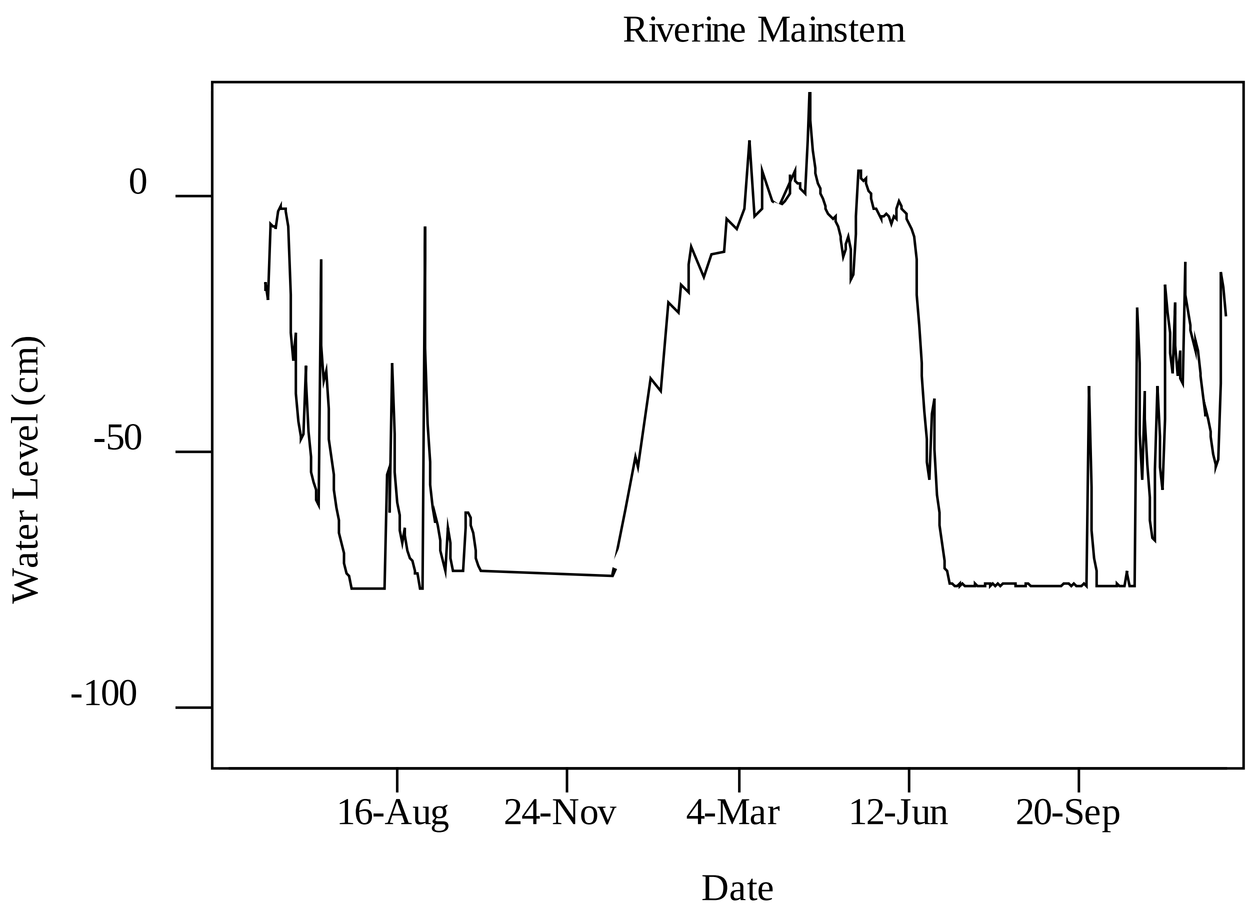

Figure 75. A natural riverine mainstem wetland hydrograph, developed from monitoring well data.