Appendix K: Population Allocation Model (PAM)

The Rein in the Runoff project team utilized the Population Allocation Model (PAM) (Koches et al. 2005) to help predict the patterns of future growth and development in the Spring Lake Watershed. PAM uses patterns of past development to predict the location of future urban and exurban growth. It was first created by researchers at the Annis Water Resources Institute (AWRI) to model expected landscape changes resulting from new residential development (Koches et al. 2005). This model is not intended to predict accurate placement of future home sites within a defined region, but it provides a way to test competing management scenarios and economic development strategies through the integration of environmental impact analysis. PAM is a planning aid for land use decision-makers; it is not a quantitative assessment tool.

POTENTIAL FUTURE GROWTH AND LAND USE CHANGE

The Population Allocation Model (PAM) was developed by AWRI as a distribution model intended to show the potential impacts associated with various land management scenarios, and to provide land use decision-makers with a relative comparison between competing solutions to common land use management choices. During its development, a Principal Component Analysis was used to help identify those factors which have the most influence on individuals making the selection of a future home site. However, these factors are limited to what can be measured spatially, using landscape features at an appropriate scale with the use of suitable spatial analysis tools, such as GIS (geographic information system). While a “great school district” or the relationship of family and friends may ultimately be the deciding factor in making the choice for the site for new home construction, these factors cannot be considered by PAM because they do not have a spatial component that is measurable on a map with GIS.

Weights assigned to each home site selection factor vary depending on the preferences of those involved. Pairwise comparison of all factors is employed to normalize the weighted scores for each factor, but results are still subjective. Therefore, AWRI employs a calibration technique to approximate the residential development that would occur for a past time period, and compares PAM results to the known land use changes for that same period. This provides a reasonable approximation of spatial patterns for a given, project-defined area.

After this calibration, factor weights are adjusted so that a similar spatial pattern is used to predict future growth and development. This is a subjective approach that limits the model outcomes by the type and number of factors used and the experience of the researchers making these weight adjustments. Given the similarity in landscape features for the undeveloped areas of West Michigan, it is difficult to distinguish between parcels using the limited types and number of factors currently employed by PAM, and model accuracy is considerably improved when using proximity analysis instead of point-by-point relationships. Whatever error lies inherent in the model would be consistently observed regardless of the management scenario being tested. PAM can approximate the general character of a known landscape without the highly precise identification of future individual building sites. This is considered sufficient for most

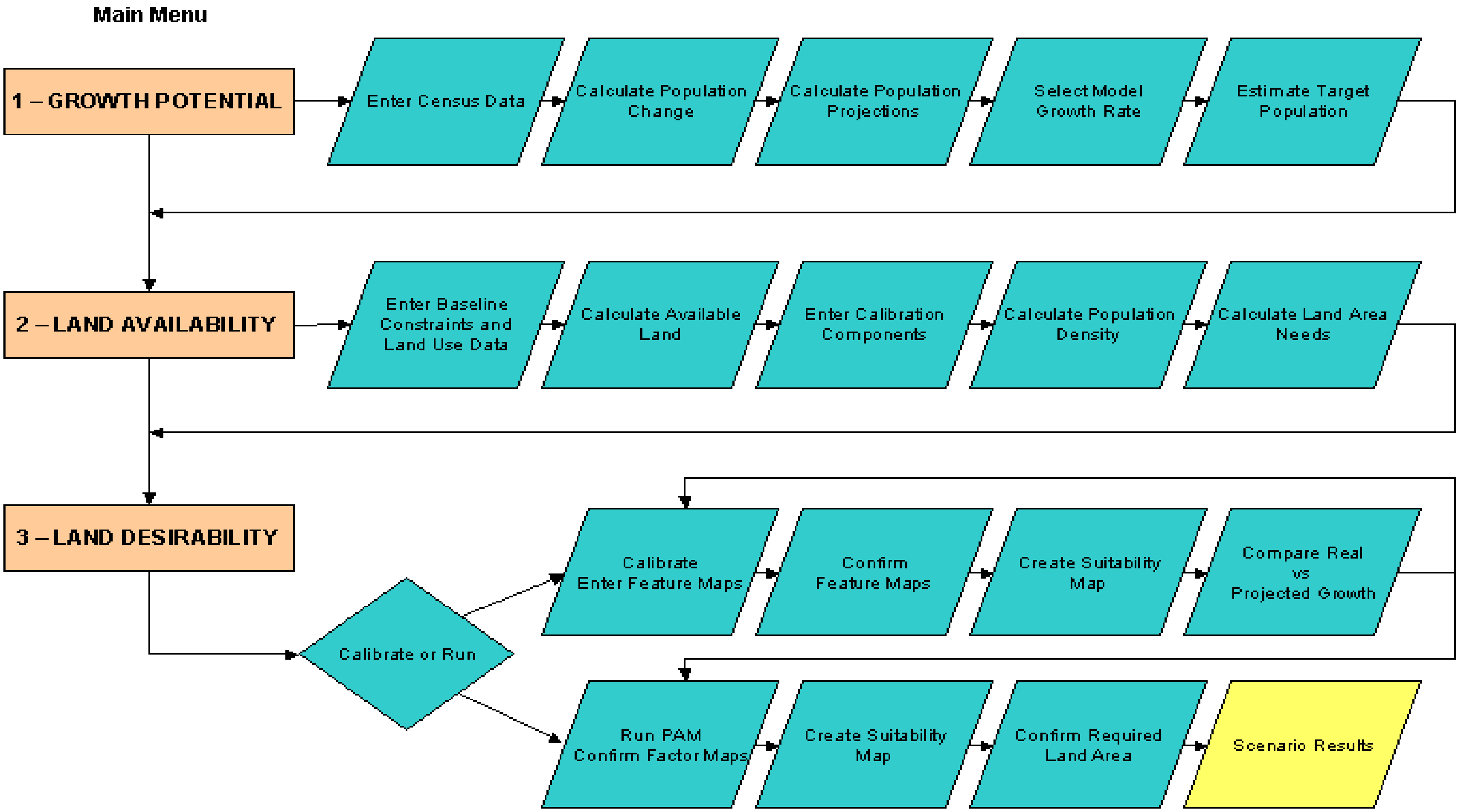

Figure K-1. Population Allocation Model (PAM) flow chart showing model components.

general land management assessments, including, for example, stormwater management assessments where impacts resulting from new residential development are dependent on soils, proximity to lakes and streams, topography, etc., and not on the exact location of a particular new home relative to its placement along a residential street.

PAM analysis has been tested in several communities in West Michigan for comparison of competing land use management scenarios. It has been paired with hydrologic models, impervious surface models, and nonpoint source pollution models to characterize the expected impacts of future residential growth and development on nearby lakes and streams. It was designed as a local land use management tool, and has never been submitted for academic peer review.

For the Rein in the Runoff project, PAM was used only to explore different scenarios of population growth and land use change, and not as a predictive model. The following sections will provide a description of the Rein in the Runoff project team's methodology and results for each of PAM's primary model components: Growth Potential Module, Land Availability Module, and Land Desirability Module (Figure K-1).

GROWTH POTENTIAL MODULE

The Growth Potential Module uses population data, most often from the U.S. Census Bureau, to calculate the population dynamics of the study area. The user enters population totals from previous years into PAM, and is then presented with summary statistics intended to describe the actual population change that has occurred within the community. This includes the amount of population growth that occurred during each 10-year census period and the total amount of change that occurred for the cumulative time period identified (whatever that may be). The location of the population is determined by the distribution of existing residential land use; PAM distributes the target population throughout the defined landscape using a variety of techniques based on known or estimated people-per-acre ratios or on a set rate of population growth. The Growth Potential Module allows the user to incorporate an exaggerated growth rate to demonstrate unsustainable growth, or even a rate less than estimated by the U.S. Census Bureau (e.g., loss of a major employer), as long as the net change over time is positive.[1] The end result is a population target for upcoming years (e.g., 2010, 2020, 2030, and 2040) using a growth rate calculated from past U.S. census data or an independently-derived estimate.

However, since PAM was originally designed for use in areas with distinct boundaries such as villages, cities, and townships, the Rein in the Runoff project was its first application at the watershed-scale. This posed a unique set of issues for calculating the population of a land area for which population data were not easily determined. The primary data used for PAM were from the U.S. Census Bureau's Decennial Census,

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[1] PAM analysis cannot be performed for areas that have experienced losses in population.

which is collected and reported for different geographic units (e.g., state, county, township, city, village, or zip code), but not at the watershed level. Because of this, the Rein in the Runoff project team had to develop a method for estimating the population for the entire Spring Lake Watershed.

For each of the municipalities that make up the Spring Lake Watershed, the project team had to determine the population of each municipality that resides within the watershed boundary. To do this, team members took the percentage of land area within the watershed for each municipal unit and multiplied it by the U.S. Census population data for 1960, 1970, 1980, 1990, and 2000. This assumed that the population was evenly distributed throughout the municipal unit, but provided a reasonable estimate for the watershed's population.

However, three watershed municipalities – Fruitport Township, Ravenna Township, and Spring Lake Township – required additional calculations. Each of these municipalities contains another municipal unit (village) completely within its borders. To adjust for this, the area of each village was subtracted from the township area prior to the population calculation. In Fruitport Township, the Village of Fruitport is completely within the Spring Lake Watershed, so its population was added back into the watershed total. In Ravenna Township, the Village of Ravenna is completely outside of the watershed and was accordingly excluded. Spring Lake Township includes the Village of Spring Lake within its borders, but approximately 70% of the Village is outside of the Spring Lake Watershed. Once the township's population was calculated, the Village population within the watershed (29.4%) was also calculated and added back into the total for the entire watershed.

It should be noted that distribution and growth rates of a population are variables that are intended to be manipulated: PAM was created to examine different future scenarios based on a variety of population growth estimates and development trends. All that the model requires is the mean number of people living on each acre of current residential land use, and how many people are expected to live in any locality in the future. PAM uses this people-per-acre ratio to determine how much land will be necessary to accommodate the expected growth, and then determines where within the landscape these new home sites are located, given past development patterns.

Table K-1. Population Allocation Model (PAM) Growth Potential Module Estimates for Spring Lake Watershed Population Over Time.

Year	Estimated Population	Population Change	Percent Change
1960	11,134		
1970	13,894	+2,760	24.79%
1980	15,363	+1,469	10.57%
1990	16,700	+1,337	8.70%
2000	18,979	+,2,279	13.65%
1960-2000		+7,845	70.46%

The estimated 2000 population for the Spring Lake Watershed is 18,979 (Table K-1)[2], which represents an increase in watershed population of nearly 14% since 1990 – and more than 70% since 1960.

LAND AVAILABILITY MODULE

The Land Availability Module uses population and land use statistics from the past and present to calculate former and existing population densities so that users can determine if there is sufficient land to accommodate projected growth. To run the module, users must first identify any land use type or other area that is unavailable for new development. For example, land that is already developed, or land uses or areas identified for preservation (e.g., wetlands or riparian setbacks), are not available for new development. These “constraints” are entered into PAM as Boolean GIS map layers that instruct the model where growth is not allowed to occur. PAM compares these excluded areas to a map of existing land uses, and identifies where, what kind, and how much available land exists for new development.

The Rein in the Runoff project team initially considered the use of local community Master Plans to develop constraint maps for use with PAM. However, because of the variability among the Spring Lake Watershed municipalities in their land use classifications, exceptions, enforcement, relevance, and even the existence of such plans, the team felt that their use would not be a good indicator of land availability for the entire watershed. In general, the most important reason for including a Master Plan as a constraint overlay is to ensure that PAM does not identify industrial or commercial areas as locations for future home sites. Preliminary model runs for the Spring Lake Watershed indicated that such conflicts were rare and did not justify the added effort and expense to include the Master Plan overlays.

Accordingly, the project team developed a residential constraint map and a general constraint map identifying roads, waterways, wetlands, and parkland for use with this module. Applying these data, along with current (2006) land use and cover data, PAM calculated total acres available for new development; total acres currently classified as residential; current (2000) census population; an estimated study population at the time of the most recent land use and land cover survey; and an estimated population for the baseline land use and land cover survey. To determine how much land in the Spring Lake Watershed was actually available for development and growth, PAM then used a model-calculated or researcher-defined population density (people/acre), to be used to allocate future population projections (Table K-2).

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[2] The estimated population for the Spring Lake Watershed listed in Table K-1 was calculated from U.S. Census Bureau tract-level data. This differs from the watershed population estimate listed in Figure 2-5 (Chapter 2), which was calculated utilizing U.S. Census Bureau block-level data.

Table K-2. PAM Population Density Calculations for the Spring Lake Watershed.

Population Density Factors	Model Results
Total watershed acres available for new development	19,219
Total watershed acres currently classified as residential (2006 land use and cover)	9,433
Watershed population (2000 U.S. Census)	18,979
Estimated watershed population based on 2006 land use and land cover	20,346
Estimated watershed population at baseline (1978) land use and land cover	15,069
PAM Estimate for Current Population Density for the Spring Lake Watershed	**2.16 persons/acre**

Finally, the Land Availability Module took the projected future population for the Spring Lake Watershed and determined the amount of land (acres) required to support it. The Rein in the Runoff project team utilized three different population growth scenarios to determine where and how much land was available for development in the Spring Lake Watershed for the years 2010, 2020, 2030, and 2040. Scenario 1 utilized actual population growth over time (1.76%) within the Spring Lake Watershed (U.S. Census Bureau 2009); Scenario 2 assumed that the population in the watershed remained stable (0.00%); and Scenario 3 assumed a slightly accelerated population growth rate (2.00%). In each of these scenarios, the population density was held constant at 2.16 people/acre (Table K-3).

Table K-3. PAM Land Availability Module Projected Growth and Development in the Spring Lake Watershed.

Year	Expected Population Increase			Land Area Required to Accommodate New Development (acres)		
	Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2	Scenario 3
2010	3,343	0	3,796	1,547.69	0	1,757.41
2020	3,932	0	4,555	1,820.37	0	2,108.80
2030	4,625	0	5,466	2,141.20	0	2,530.56
2040	5,439	0	6,559	2,518.06	0	3,036.57
Total	**17,339**	**0**	**20,376**	**8,037.21**	**0**	**9,433.33**

LAND DESIRABILITY MODULE

The Land Desirability Module examines former land use trends in an attempt to understand what factors in the past landscape influenced decisions to build new homes, in order to forecast where people are likely to live in the future within the given landscape. The module employs six factors: (1) distance to water features, such as lakes and streams; (2) distance to roads; (3) the location of existing residential development; (4) distance to forest lands; (5) septic system suitability; and (6) slope. These factors can be weighted by stakeholder input, or with a decision support system such as analytical hierarchy process (Saaty 1990), which is available within IDRISI, the GIS software used as the spatial platform for PAM analysis (IDRISI Andes, Clark Labs at Clark University (idrisi@clark.edu). After calibration of PAM using these assigned weights, the module is then ready for scenario analysis of what the community will look like into the future. The default module settings will provide an approximation of the status quo, but users can also modify the constraint map in the Land Availability Module to incorporate new zoning restrictions, or apply a new weighting curve to the water proximity factor if, for example, stream corridor setback widths are increased. What is important is not that PAM captures the exact location of an existing home site, but rather the actual “pattern of development” that occurred.

The Rein in the Runoff project team first calibrated PAM using the default weights generated by the analytical hierarchy process within the model. The decision support file (Table K-4) was constructed to satisfy the IDRISI format necessary to process the subsequent macro. The first number in the array, and in this case “0”, indicated that no constraint map was used. The second number told IDRISI that there were 6 factor maps. What remained in the array were the file names for each factor listed above (water, roads, residential development, forests, septic system suitability, and slope) followed by its associated weight. These weights, which add up to 1.0, provide the user with information regarding the relative importance of each factor in the underlying analysis. For example, the road factor is given the greatest weight in the calibration model, and in fact is weighted 10 times higher than septic system suitability, the least weighted factor.

Table K-4. PAM Decision Support File for the Spring Lake Watershed.

0
6
Waterfactst
0.1936
Roadfactst
0.3519
Resfactst
0.2672
Forestfactst
0.1112
Septicfactst
0.0323
Slopefactst
0.0438

Calibrating the model based on past land use and cover gives an indication of PAM model accuracy, as well as information regarding community development patterns. The project team used 1978 land use and land cover data for the Spring Lake Watershed to generate PAM factor maps for hydrology, roads, historic forest lands, slope, septic system suitability, historic residential lands, and historic residential growth (increases in residential land cover from 1978 and 2000). PAM then integrated these underlying factor maps to predict the best places to build within the watershed based on the model-defined weighting system and the population density calculated in the Land Availability Module. These were compared to actual residential development in the Spring Lake Watershed from 1978 to 1998.

The Land Desirability Module calibration indicated that PAM correctly predicted future development for the Spring Lake Watershed for 16.7% of the pixels (1 pixel = 1 acre) that make up the spatial data for the watershed. Compared to previous model runs on other study areas in West Michigan, this was a very good result. PAM depends on only a limited number of factors to rank parcels for selection of potential future residential development. Because the model uses GIS technology as the basis for its predictions, it relies on factors which can be described in a spatial context, such as distance to roads, distance to current residential development, and the location of suitable soils for installation of septic systems. There are, of course, many other factors potential homeowners use in the selection of a new home site that are not easily spatially-defined: quality of schools, availability of building contractors, real estate price, character of existing housing/neighborhoods, and the influence of friends and family. The calibration confirmed that the pattern of development within the Spring Lake Watershed conformed to research expectations as to where future development would have occurred. So, despite the limitations of the model, PAM provided valuable information for stakeholders about how their decisions regarding future growth affect the “build-out” of their community.

After calibration, the second component of the Land Desirability Module was implemented. PAM predicted the distribution of future residential land use throughout the watershed. New factor maps were created for forested and residential areas using current land use and cover data (2006), and PAM generated the expected population growth and the amount of land required for this growth to occur into the future (2010, 2020, 2030, and 2040). The spatial allocations for this projected growth are also mapped by PAM for each future timeframe: 2010 (Figure K-2), 2020 (Figure K-3), 2030 (Figure K-4), and 2040 (Figure K-5). These maps show where the projected, growing population for each time period is expected to develop within the Spring Lake Watershed.

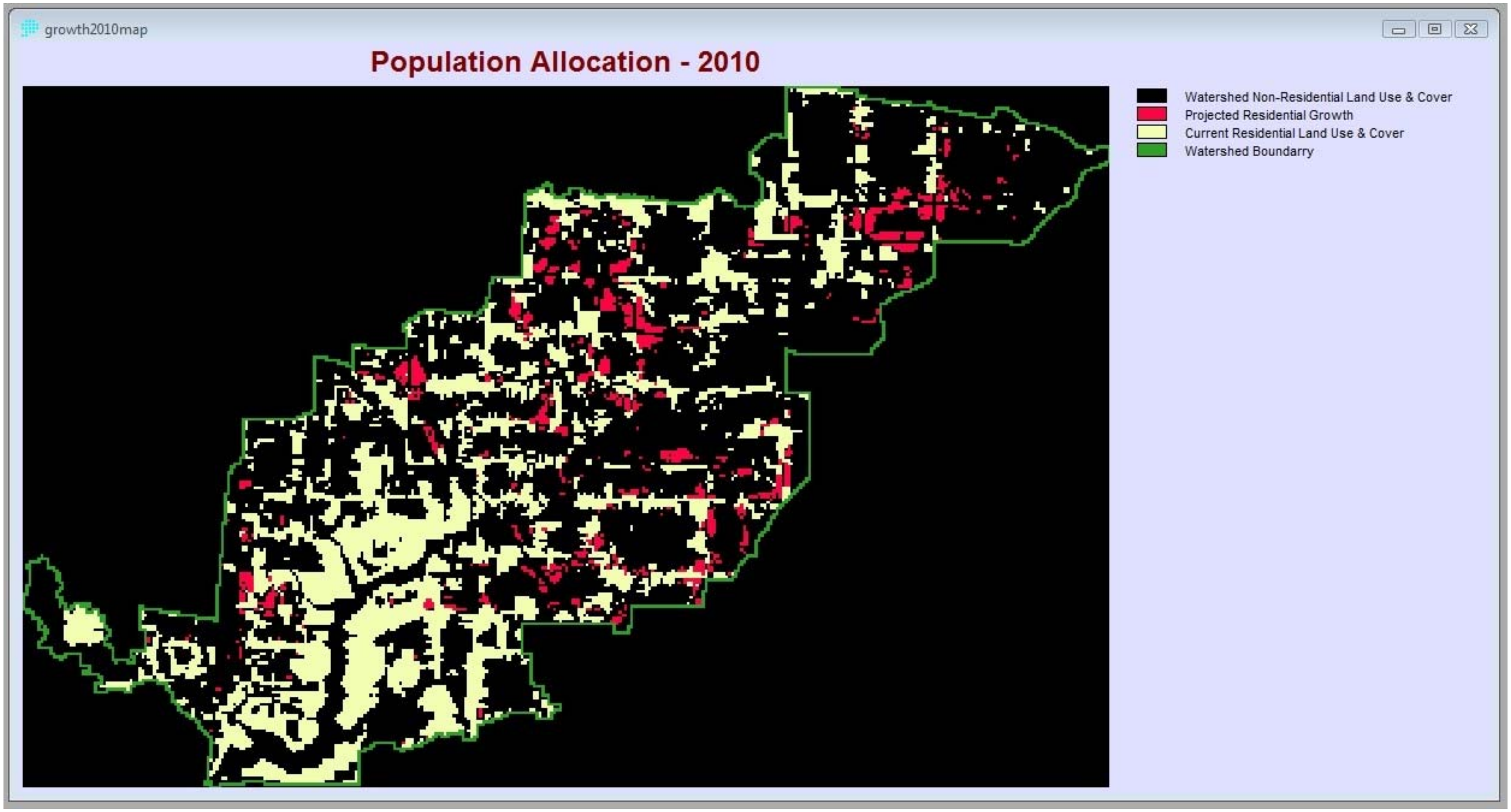

Figure K-2. PAM population growth and allocation map for the Spring Lake Watershed for 2010.

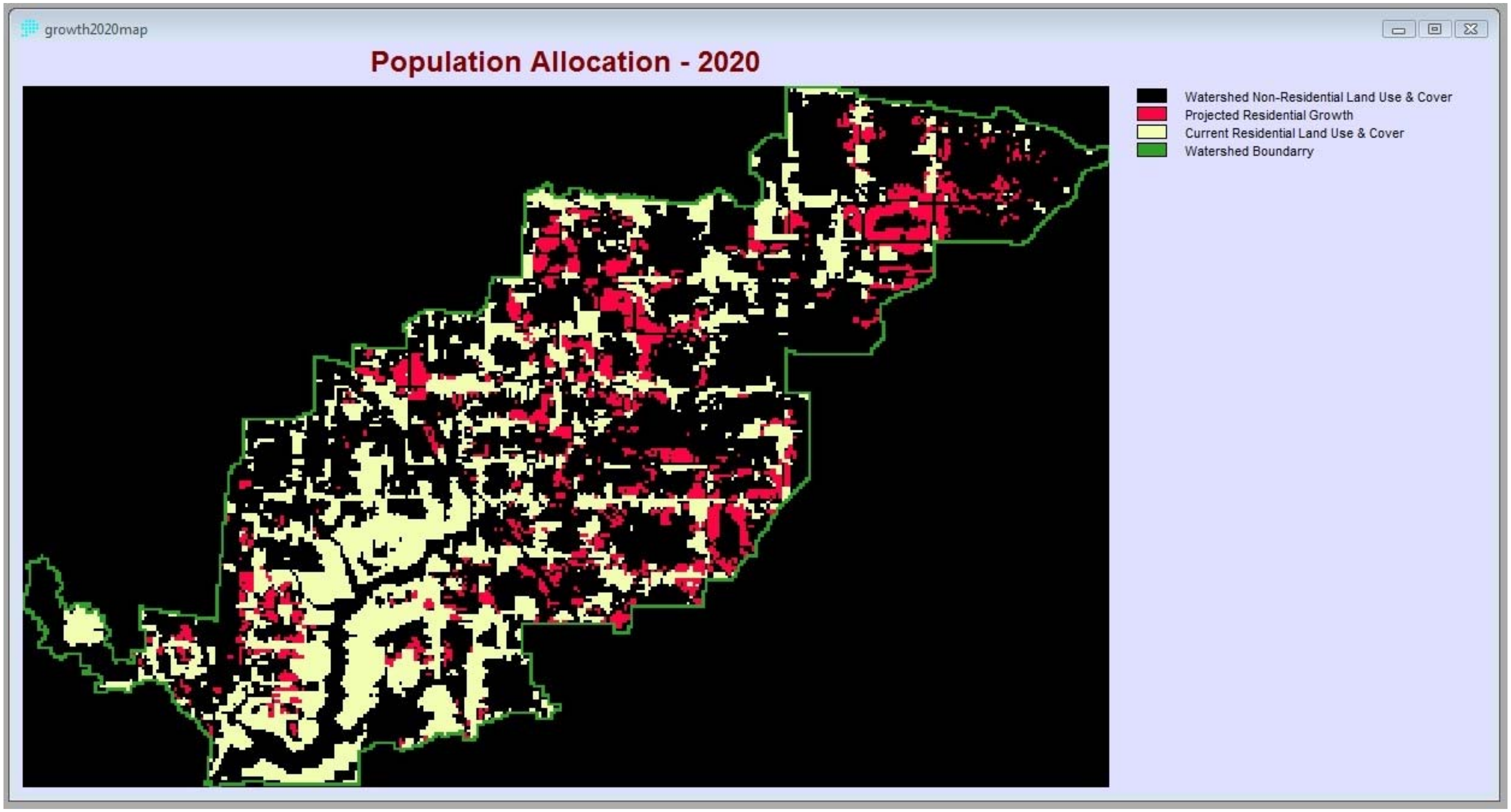

Figure K-3. PAM population growth and allocation map for the Spring Lake Watershed for 2020.

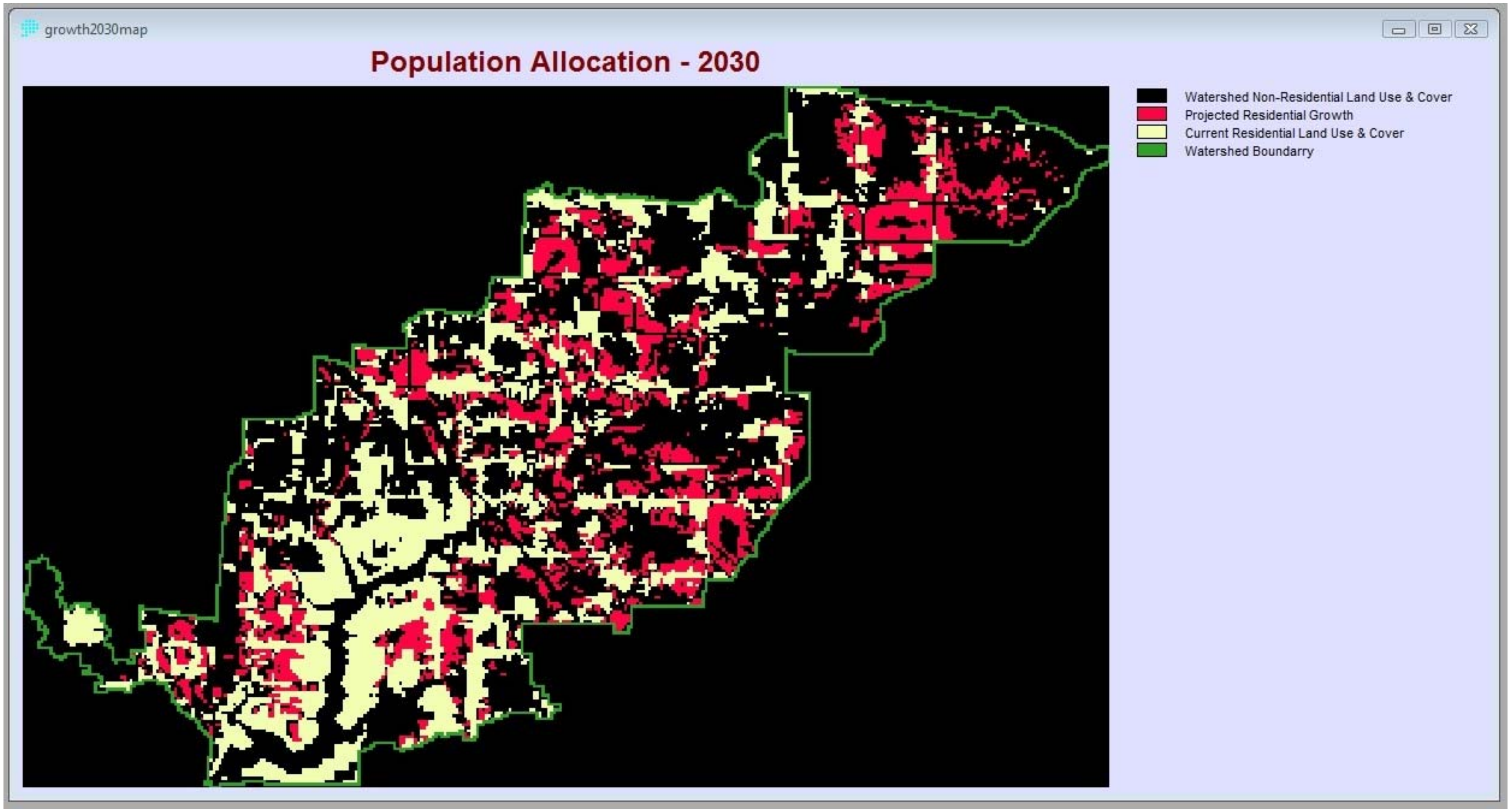

Figure K-4. PAM population growth and allocation map for the Spring Lake Watershed for 2030.

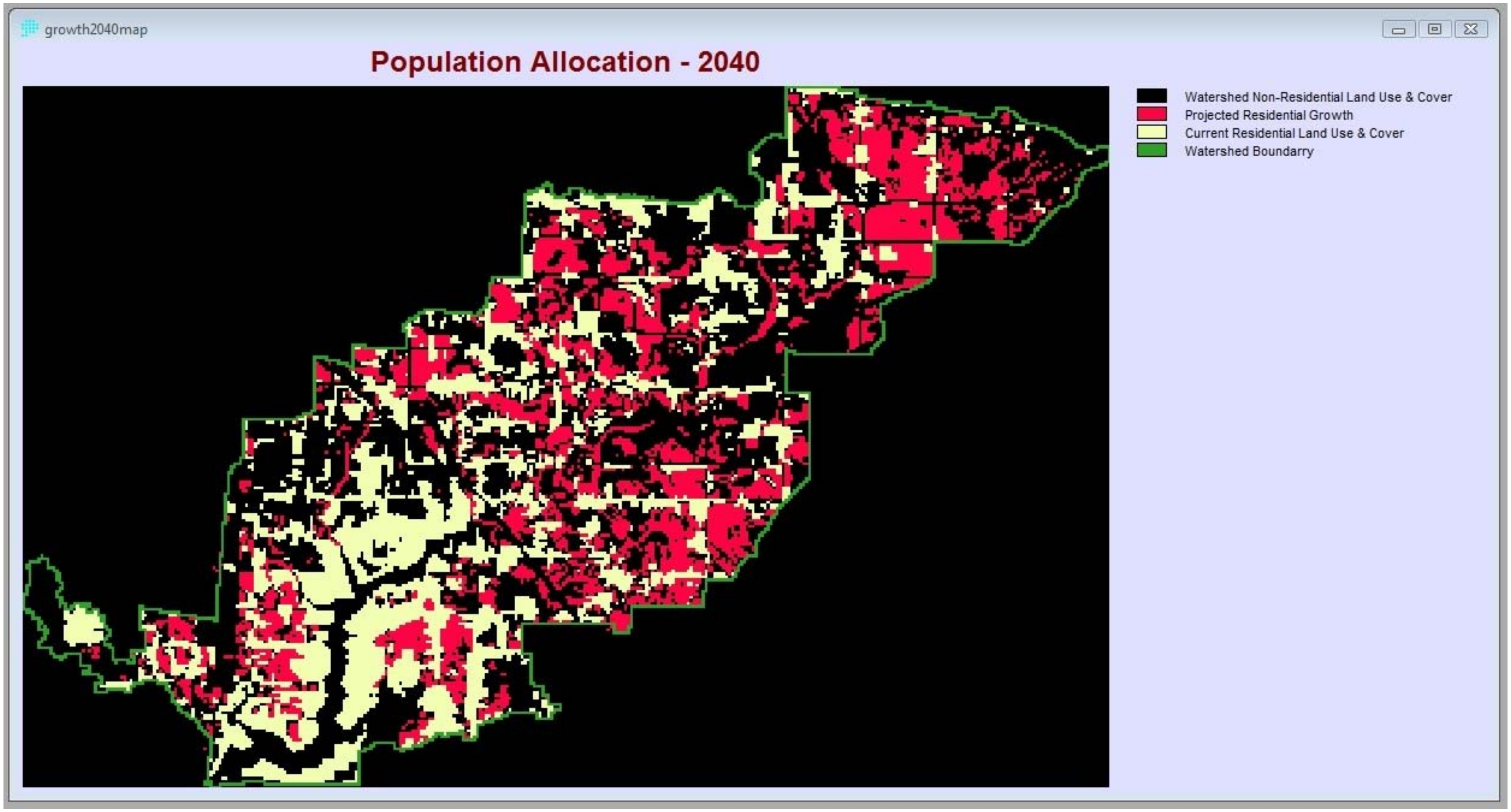

Figure K-5. PAM population growth and allocation map for the Spring Lake Watershed for 2040.