# GAM run 06-25

**by Richard Smith, P.G.**
Texas Water Development Board
Groundwater Availability Modeling Section
(512) 936-0877
November 2, 2006

## REQUESTOR:

Mr. C.E. Williams with the Panhandle Groundwater Conservation District on behalf of Groundwater Management Area 1 (GMA 1).

## DESCRIPTION OF REQUEST:

Determine the groundwater remaining in storage for each county in GMA 1 using 1, 1.25, and 1.5 percent annual depletion from the base year of 2000 for the time period of 2000 through 2060 using average annual recharge.

## METHODS:

To address the request, we did the following steps:

- Extracted the annual model-wide recharge rates from the water budgets from the groundwater availability model (GAM) runs for the northern and southern parts of the Ogallala Aquifer. Average recharge is based on a percentage of precipitation for the 1950 through 1990 period of record.
- Calculated the groundwater in storage for the baseline year 2000 using unique cell values. To do so, we first calculated saturated thickness by subtracting the bottom of the Ogallala Aquifer, as included in the GAM, from the simulated and calibrated GAM water levels in 2000. On a cell-by-cell basis in the GAM, we multiplied the saturated thickness by the area of the cell and by the model cell's specific yield to get a volume. Previous estimates had used an average value of 0.15 for the specific yield across the models (GAM Run 04-13 dated September 22, 2004), and we felt that using unique values for each cell in the GAM was more appropriate; and
- Computed the 1, 1.25, and 1.5 percent annual depletion from 2000 through 2060 using a spreadsheet analysis. Annual depletion was calculated based on a depletion of the previous year's total storage with the addition of average recharge.

## PARAMETERS AND ASSUMPTIONS:

- Used version 2.01 of the GAM for the northern part of the Ogallala Aquifer (2004, Dutton) and version 1.01 of the GAM for the southern part of the Ogallala Aquifer (2003, Blandford and others),

- See Dutton and others (2001) and Dutton (2004) for assumptions and limitations of the GAM for the northern part of the Ogallala Aquifer. Root mean squared error for this model is 53 feet. This error has more of an effect on model results where the aquifer is thin.
- See Blandford and others (2003) for assumptions and limitations of the GAM for the southern part of the Ogallala Aquifer. Root mean squared error for this model is 47 feet. This error will have more of an effect on model results where the aquifer is thin.
- Recharge was reappraised in the updated GAM of the northern part of the Ogallala Aquifer (Dutton, 2004).
- Average recharge used in both of the GAMs was based on a percentage of precipitation for the 1950 through 1990 period of record. Since this includes the 1950s drought of record, the average recharge used for this analysis is considered a conservative estimate.
- The predictive simulations were based on pumpage provided by the planning group for Region A as discussed in GAM run 05-09
- For Randall and Potter counties, which are partially included in both the northern and southern parts of the GAMs, we combined the results to get full county totals.

## RESULTS:

Table 1 shows the results of our analysis. Graphical results follow with Figures 1 through 19.

## REFERENCES:

Dutton, A., 2004, Adjustments of parameters to improve the calibration of the Og-N model of the Ogallala aquifer, Panhandle Water Planning Area: Bureau of Economic Geology, The University of Texas at Austin, 9 p

Blandford, T. N., Blazer, D. J., Calhoun, K. C., Dutton, A. R., Naing, T., Reedy, R. C., and Scanlon, B. R., 2003, Groundwater availability of the southern Ogallala aquifer in Texas and New Mexico; Numerical Simulations Through 2050: Final Report prepared for the Texas Water Development Board by Daniel B. Stephens & Associates, Inc., 158 p.

Dutton, A., Reedy, R., and Mace, R., 2001, Saturated thickness of the Ogallala aquifer in the Panhandle Water Planning Area – Simulation of 2000 through 2050 Withdrawal Projections: prepared for the Panhandle Water Planning Group by the Bureau of Economic Geology, The University of Texas at Austin, 54 p.

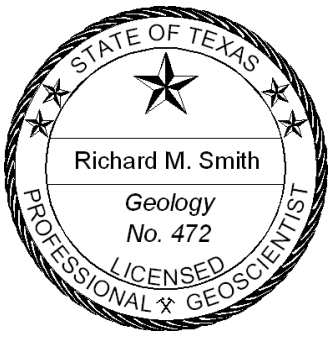


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**Table 1.Groundwater remaining in storage for the Ogallala Aquifer for each county in GMA 1. Calculation starts in 2000 and assumes 1, 1.25, and 1.5 percent decrease in volume for each year with the addition of average recharge. All values are reported in acre-feet per year.**

| County | Recharge | 2000 | 1 % per Year Reduction in Storage Volume-2010 | 1.25% per Year Reduction in Storage Volume-2010 | 1.5% per Year Reduction in Storage Volume-2010 | GAM Results Storage Volume-2010 |
|---|---|---|---|---|---|---|
| Armstrong | 4,745 | 4,051,267 | 3,709,264 | 3,617,283 | 3,527,370 | 3,946,527 |
| Carson | 8,218 | 15,280,781 | 13,898,243 | 13,552,330 | 13,214,202 | 14,159,377 |
| Collingsworth | 252 | 85,870 | 80,069 | 78,103 | 76,182 | 85,792 |
| Dallam | 21,547 | 17,604,513 | 16,127,234 | 15,727,439 | 15,336,628 | 14,622,921 |
| Donley | 14,287 | 6,249,296 | 5,788,361 | 5,645,737 | 5,506,312 | 6,071,878 |
| Gray | 16,694 | 13,648,169 | 12,502,784 | 12,192,838 | 11,889,857 | 13,287,191 |
| Hansford | 7,670 | 21,693,703 | 19,692,735 | 19,202,075 | 18,722,461 | 20,385,024 |
| Hartley | 17,045 | 24,925,026 | 22,704,727 | 22,140,111 | 21,588,197 | 22,140,753 |
| Hemphill | 31,416 | 15,638,152 | 14,443,258 | 14,086,817 | 13,738,376 | 15,587,716 |
| Hutchinson | 15,821 | 11,112,029 | 10,200,797 | 9,948,210 | 9,701,297 | 10,275,488 |
| Lipscomb | 20,459 | 18,640,279 | 17,053,559 | 16,630,491 | 16,216,934 | 18,526,166 |
| Moore | 7,631 | 10,662,411 | 9,715,859 | 9,474,292 | 9,238,159 | 8,866,273 |
| Ochiltree | 8,819 | 19,795,557 | 17,987,072 | 17,539,151 | 17,101,312 | 18,847,872 |
| Oldham | 4,042 | 2,521,470 | 2,319,021 | 2,261,658 | 2,205,582 | 2,464,330 |
| Potter | 3,537 | 3,045,673 | 2,788,272 | 2,719,126 | 2,651,533 | 2,857,232 |
| Randall | 24,940 | 6,258,380 | 5,898,438 | 5,754,480 | 5,613,741 | 5,846,443 |
| Roberts | 24,049 | 27,494,610 | 25,095,584 | 24,472,204 | 23,862,843 | 26,805,037 |
| Sherman | 7,654 | 19,498,315 | 17,707,113 | 17,266,027 | 16,834,870 | 16,814,464 |
| Wheeler | 24,111 | 7,485,439 | 7,000,241 | 6,828,664 | 6,660,929 | 7,423,165 |

Table 1 (cont.)

| County | Recharge | 2000 | 1% per Year Reduction in Storage Volume-2020 | 1.25% per Year Reduction in Storage Volume-2020 | 1.5% per Year Reduction in Storage Volume-2020 | GAM Results Storage Volume-2020 |
|---|---|---|---|---|---|---|
| Armstrong | 4,745 | 4,051,267 | 3,399,963 | 3,234,595 | 3,076,959 | 3,841,987 |
| Carson | 8,218 | 15,280,781 | 12,647,901 | 12,028,179 | 11,437,500 | 13,081,706 |
| Collingsworth | 252 | 85,870 | 74,822 | 71,254 | 67,852 | 85,703 |
| Dallam | 21,547 | 17,604,513 | 14,791,209 | 14,072,231 | 13,386,859 | 12,134,853 |
| Donley | 14,287 | 6,249,296 | 5,371,499 | 5,113,517 | 4,867,546 | 5,906,044 |
| Gray | 16,694 | 13,648,169 | 11,466,918 | 10,909,524 | 10,378,183 | 12,937,973 |
| Hansford | 7,670 | 21,693,703 | 17,883,096 | 17,004,953 | 16,167,994 | 19,092,753 |
| Hartley | 17,045 | 24,925,026 | 20,696,729 | 19,684,367 | 18,719,423 | 19,612,912 |
| Hemphill | 31,416 | 15,638,152 | 13,362,617 | 12,718,848 | 12,105,081 | 15,537,912 |
| Hutchinson | 15,821 | 11,112,029 | 9,376,695 | 8,921,951 | 8,488,447 | 9,463,673 |
| Lipscomb | 20,459 | 18,640,279 | 15,618,558 | 14,858,256 | 14,133,510 | 18,413,261 |
| Moore | 7,631 | 10,662,411 | 8,859,815 | 8,426,607 | 8,013,686 | 7,116,002 |
| Ochiltree | 8,819 | 19,795,557 | 16,351,511 | 15,549,449 | 14,784,988 | 17,955,425 |
| Oldham | 4,042 | 2,521,470 | 2,135,930 | 2,032,555 | 1,934,004 | 2,431,378 |
| Potter | 3,537 | 3,045,673 | 2,555,483 | 2,431,176 | 2,312,680 | 2,716,565 |
| Randall | 24,940 | 6,258,380 | 5,572,913 | 5,310,141 | 5,059,526 | 5,475,627 |
| Roberts | 24,049 | 27,494,610 | 22,925,948 | 21,807,040 | 20,740,502 | 26,098,600 |
| Sherman | 7,654 | 19,498,315 | 16,087,181 | 15,297,591 | 14,545,025 | 14,188,402 |
| Wheeler | 24,111 | 7,485,439 | 6,561,437 | 6,249,519 | 5,952,073 | 7,367,619 |

Table 1 (cont.)

| County | Recharge | 2000 | 1% per Year Reduction in Storage Volume-2030 | 1.25% per Year Reduction in Storage Volume-2030 | 1.5% per Year Reduction in Storage Volume-2030 | GAM Results Storage Volume-2030 |
|---|---|---|---|---|---|---|
| Armstrong | 4,745 | 4,051,267 | 3,120,236 | 2,897,140 | 2,689,727 | 3,762,122 |
| Carson | 8,218 | 15,280,781 | 11,517,114 | 10,684,180 | 9,910,016 | 12,044,288 |
| Collingsworth | 252 | 85,870 | 70,078 | 65,215 | 60,691 | 85,608 |
| Dallam | 21,547 | 17,604,513 | 13,582,932 | 12,612,665 | 11,710,583 | 10,126,050 |
| Donley | 14,287 | 6,249,296 | 4,994,497 | 4,644,205 | 4,318,380 | 5,754,021 |
| Gray | 16,694 | 13,648,169 | 10,530,100 | 9,777,895 | 9,078,550 | 12,604,708 |
| Hansford | 7,670 | 21,693,703 | 16,246,490 | 15,067,527 | 13,971,842 | 17,850,094 |
| Hartley | 17,045 | 24,925,026 | 18,880,732 | 17,518,888 | 16,253,051 | 17,620,595 |
| Hemphill | 31,416 | 15,638,152 | 12,385,304 | 11,512,569 | 10,700,887 | 15,492,137 |
| Hutchinson | 15,821 | 11,112,029 | 8,631,392 | 8,016,995 | 7,445,723 | 8,736,497 |
| Lipscomb | 20,459 | 18,640,279 | 14,320,768 | 13,295,496 | 12,342,327 | 18,305,998 |
| Moore | 7,631 | 10,662,411 | 8,085,624 | 7,502,755 | 6,960,970 | 5,572,033 |
| Ochiltree | 8,819 | 19,795,557 | 14,872,339 | 13,794,925 | 12,793,573 | 17,118,070 |
| Oldham | 4,042 | 2,521,470 | 1,970,345 | 1,830,531 | 1,700,520 | 2,410,964 |
| Potter | 3,537 | 3,045,673 | 2,344,953 | 2,177,261 | 2,021,357 | 2,602,259 |
| Randall | 24,940 | 6,258,380 | 5,278,513 | 4,918,321 | 4,583,050 | 5,318,727 |
| Roberts | 24,049 | 27,494,610 | 20,963,768 | 19,456,893 | 18,056,130 | 25,455,105 |
| Sherman | 7,654 | 19,498,315 | 14,622,144 | 13,561,820 | 12,576,376 | 11,708,499 |
| Wheeler | 24,111 | 7,485,439 | 6,164,590 | 5,738,828 | 5,342,647 | 7,325,079 |

Table 1 (cont.)

| County | Recharge | 2000 | 1% per Year Reduction in Storage Volume-2040 | 1.25% per Year Reduction in Storage Volume-2040 | 1.5% per Year Reduction in Storage Volume-2040 | GAM Results Storage Volume-2040 |
|---|---|---|---|---|---|---|
| Armstrong | 4,745 | 4,051,267 | 2,867,256 | 2,599,572 | 2,356,812 | 3,660,019 |
| Carson | 8,218 | 15,280,781 | 10,494,450 | 9,499,038 | 8,596,792 | 11,076,423 |
| Collingsworth | 252 | 85,870 | 65,787 | 59,890 | 54,535 | 85,514 |
| Dallam | 21,547 | 17,604,513 | 12,490,189 | 11,325,618 | 10,269,437 | 8,591,459 |
| Donley | 14,287 | 6,249,296 | 4,653,543 | 4,230,365 | 3,846,245 | 5,622,240 |
| Gray | 16,694 | 13,648,169 | 9,682,858 | 8,780,022 | 7,961,217 | 12,297,143 |
| Hansford | 7,670 | 21,693,703 | 14,766,373 | 13,359,101 | 12,083,742 | 16,716,209 |
| Hartley | 17,045 | 24,925,026 | 17,238,376 | 15,609,364 | 14,132,635 | 16,366,457 |
| Hemphill | 31,416 | 15,638,152 | 11,501,440 | 10,448,870 | 9,493,659 | 15,450,805 |
| Hutchinson | 15,821 | 11,112,029 | 7,957,353 | 7,219,002 | 6,549,262 | 8,113,675 |
| Lipscomb | 20,459 | 18,640,279 | 13,147,071 | 11,917,451 | 10,802,393 | 18,210,229 |
| Moore | 7,631 | 10,662,411 | 7,385,459 | 6,688,102 | 6,055,918 | 4,394,052 |
| Ochiltree | 8,819 | 19,795,557 | 13,534,602 | 12,247,782 | 11,081,494 | 16,368,979 |
| Oldham | 4,042 | 2,521,470 | 1,820,594 | 1,652,386 | 1,499,787 | 2,354,849 |
| Potter | 3,537 | 3,045,673 | 2,154,554 | 1,953,358 | 1,770,897 | 2,417,728 |
| Randall | 24,940 | 6,258,380 | 5,012,264 | 4,572,814 | 4,173,409 | 4,932,887 |
| Roberts | 24,049 | 27,494,610 | 19,189,207 | 17,384,530 | 15,748,294 | 25,011,760 |
| Sherman | 7,654 | 19,498,315 | 13,297,191 | 12,031,214 | 10,883,868 | 9,545,592 |
| Wheeler | 24,111 | 7,485,439 | 5,805,689 | 5,288,500 | 4,818,706 | 7,288,085 |

Table 1 (cont.)

| County | Recharge | 2000 | 1% per Year Reduction in Storage Volume-2050 | 1.25% per Year Reduction in Storage Volume-2050 | 1.5% per Year Reduction in Storage Volume-2050 | GAM Results Storage Volume-2050 |
|---|---|---|---|---|---|---|
| Armstrong | 4,745 | 4,051,267 | 2,638,466 | 2,337,175 | 2,070,595 | 3,594,351 |
| Carson | 8,218 | 15,280,781 | 9,569,571 | 8,453,978 | 7,467,773 | 9,990,939 |
| Collingsworth | 252 | 85,870 | 61,906 | 55,194 | 49,242 | 85,420 |
| Dallam | 21,547 | 17,604,513 | 11,501,931 | 10,190,697 | 9,030,440 | 7,549,367 |
| Donley | 14,287 | 6,249,296 | 4,345,190 | 3,865,439 | 3,440,336 | 5,514,375 |
| Gray | 16,694 | 13,648,169 | 8,916,628 | 7,900,097 | 7,000,611 | 12,022,161 |
| Hansford | 7,670 | 21,693,703 | 13,427,782 | 11,852,607 | 10,460,485 | 15,729,410 |
| Hartley | 17,045 | 24,925,026 | 15,753,059 | 13,925,542 | 12,309,650 | 15,570,650 |
| Hemphill | 31,416 | 15,638,152 | 10,702,090 | 9,510,899 | 8,455,768 | 15,413,991 |
| Hutchinson | 15,821 | 11,112,029 | 7,347,765 | 6,515,331 | 5,778,547 | 7,629,968 |
| Lipscomb | 20,459 | 18,640,279 | 12,085,600 | 10,702,289 | 9,478,464 | 18,128,137 |
| Moore | 7,631 | 10,662,411 | 6,752,243 | 5,969,739 | 5,277,817 | 3,551,754 |
| Ochiltree | 8,819 | 19,795,557 | 12,324,777 | 10,883,509 | 9,609,566 | 15,724,576 |
| Oldham | 4,042 | 2,521,470 | 1,685,161 | 1,495,298 | 1,327,211 | 2,369,351 |
| Potter | 3,537 | 3,045,673 | 1,982,360 | 1,755,920 | 1,555,570 | 2,396,881 |
| Randall | 24,940 | 6,258,380 | 4,771,473 | 4,268,145 | 3,821,228 | 5,326,169 |
| Roberts | 24,049 | 27,494,610 | 17,584,327 | 15,557,115 | 13,764,178 | 24,689,458 |
| Sherman | 7,654 | 19,498,315 | 12,098,927 | 10,681,523 | 9,428,767 | 7,794,612 |
| Wheeler | 24,111 | 7,485,439 | 5,481,106 | 4,891,399 | 4,368,257 | 7,257,973 |

Table 1 (cont.)

| County | Recharge | 2000 | 1% per Year Reduction in Storage Volume-2060 | 1.25% per Year Reduction in Storage Volume-2060 | 1.5% per Year Reduction in Storage Volume-2060 | GAM Results Storage Volume-2060 |
|---|---|---|---|---|---|---|
| Armstrong | 4,745 | 4,051,267 | 2,431,552 | 2,105,794 | 1,824,526 | 3,516,472 |
| Carson | 8,218 | 15,280,781 | 8,733,127 | 7,532,443 | 6,497,120 | 9,189,765 |
| Collingsworth | 252 | 85,870 | 58,396 | 51,053 | 44,691 | 85,329 |
| Dallam | 21,547 | 17,604,513 | 10,608,168 | 9,189,921 | 7,965,237 | 6,779,683 |
| Donley | 14,287 | 6,249,296 | 4,066,321 | 3,543,648 | 3,091,363 | 5,424,345 |
| Gray | 16,694 | 13,648,169 | 8,223,663 | 7,124,176 | 6,174,749 | 11,774,680 |
| Hansford | 7,670 | 21,693,703 | 12,217,185 | 10,524,178 | 9,064,922 | 14,852,445 |
| Hartley | 17,045 | 24,925,026 | 14,409,765 | 12,440,745 | 10,742,374 | 15,033,727 |
| Hemphill | 31,416 | 15,638,152 | 9,979,171 | 8,683,794 | 7,563,462 | 15,381,202 |
| Hutchinson | 15,821 | 11,112,029 | 6,796,464 | 5,894,832 | 5,115,940 | 7,245,126 |
| Lipscomb | 20,459 | 18,640,279 | 11,125,625 | 9,630,756 | 8,340,242 | 18,055,287 |
| Moore | 7,631 | 10,662,411 | 6,179,574 | 5,336,285 | 4,608,859 | 2,928,227 |
| Ochiltree | 8,819 | 19,795,557 | 11,230,633 | 9,680,490 | 8,344,106 | 15,156,476 |
| Oldham | 4,042 | 2,521,470 | 1,562,678 | 1,356,777 | 1,178,841 | 2,359,118 |
| Potter | 3,537 | 3,045,673 | 1,826,631 | 1,581,819 | 1,370,446 | 2,304,503 |
| Randall | 24,940 | 6,258,380 | 4,553,706 | 3,999,487 | 3,518,448 | 5,355,003 |
| Roberts | 24,049 | 27,494,610 | 16,132,901 | 13,945,698 | 12,058,372 | 24,396,671 |
| Sherman | 7,654 | 19,498,315 | 11,015,239 | 9,491,362 | 8,177,773 | 6,390,606 |
| Wheeler | 24,111 | 7,485,439 | 5,187,558 | 4,541,235 | 3,980,993 | 7,232,521 |

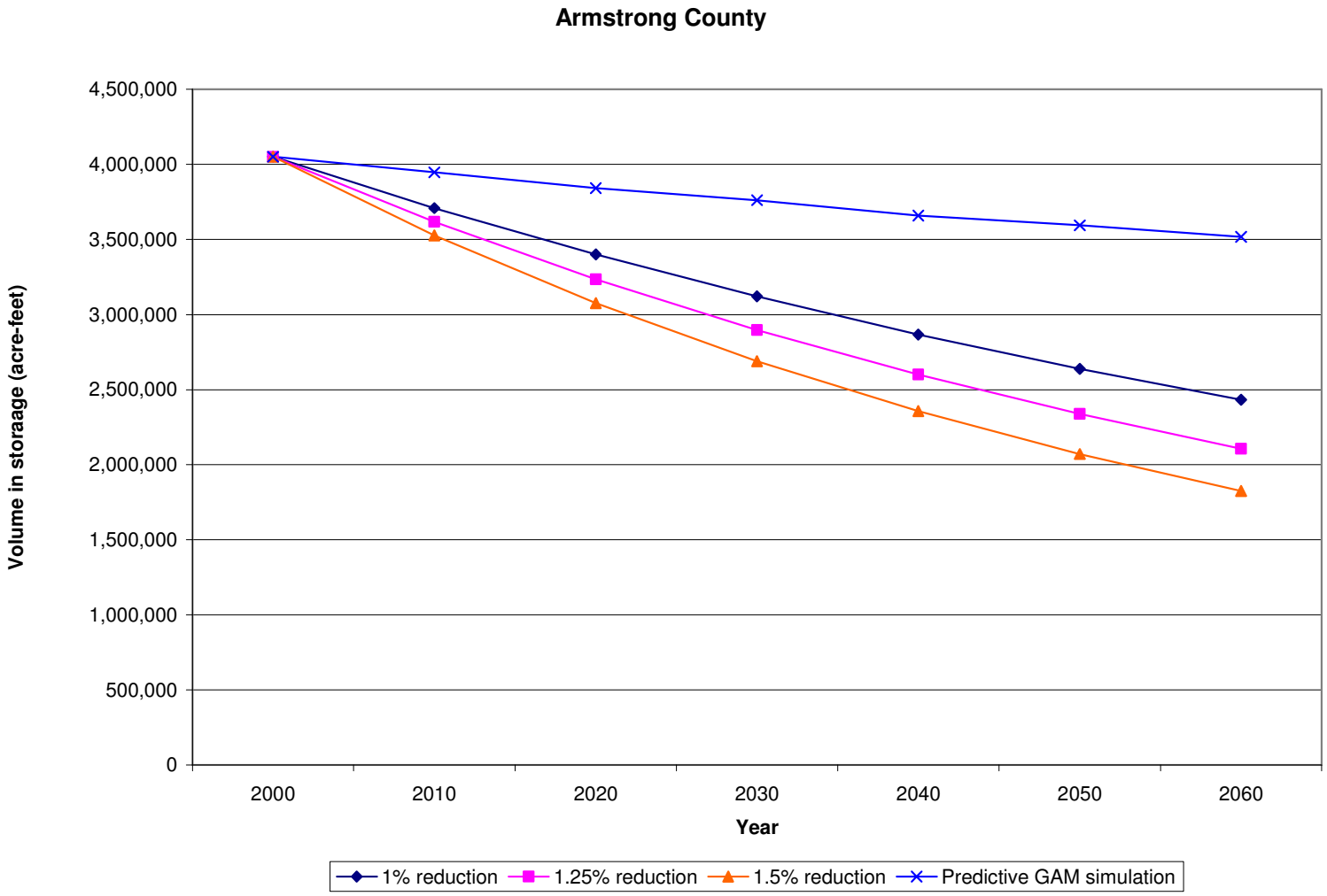


**Figure 1. Results of storage reduction analysis of the Ogallala Aquifer in Armstrong County.**

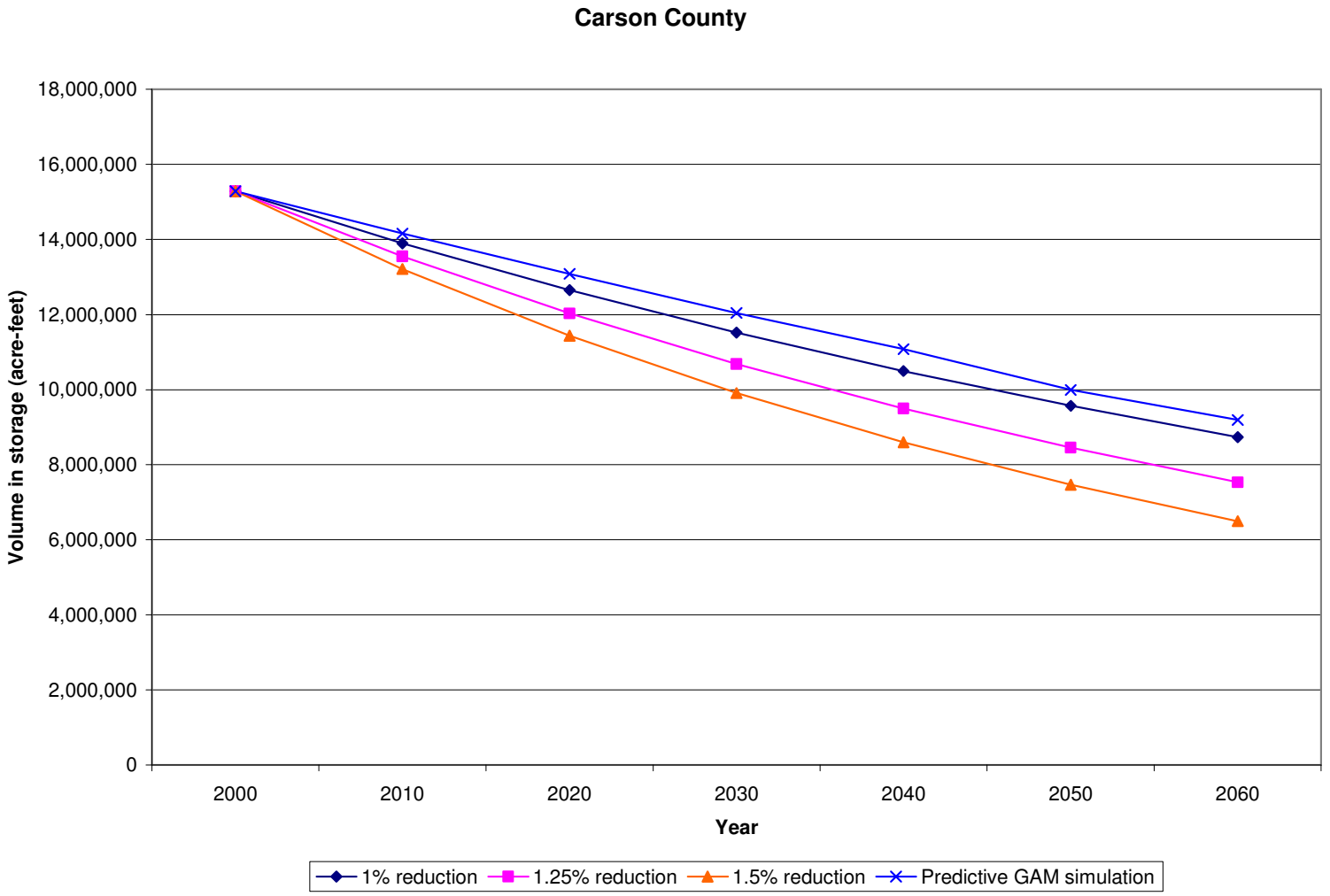


**Figure 2. Results of storage reduction analysis of the Ogallala Aquifer in Carson County.**

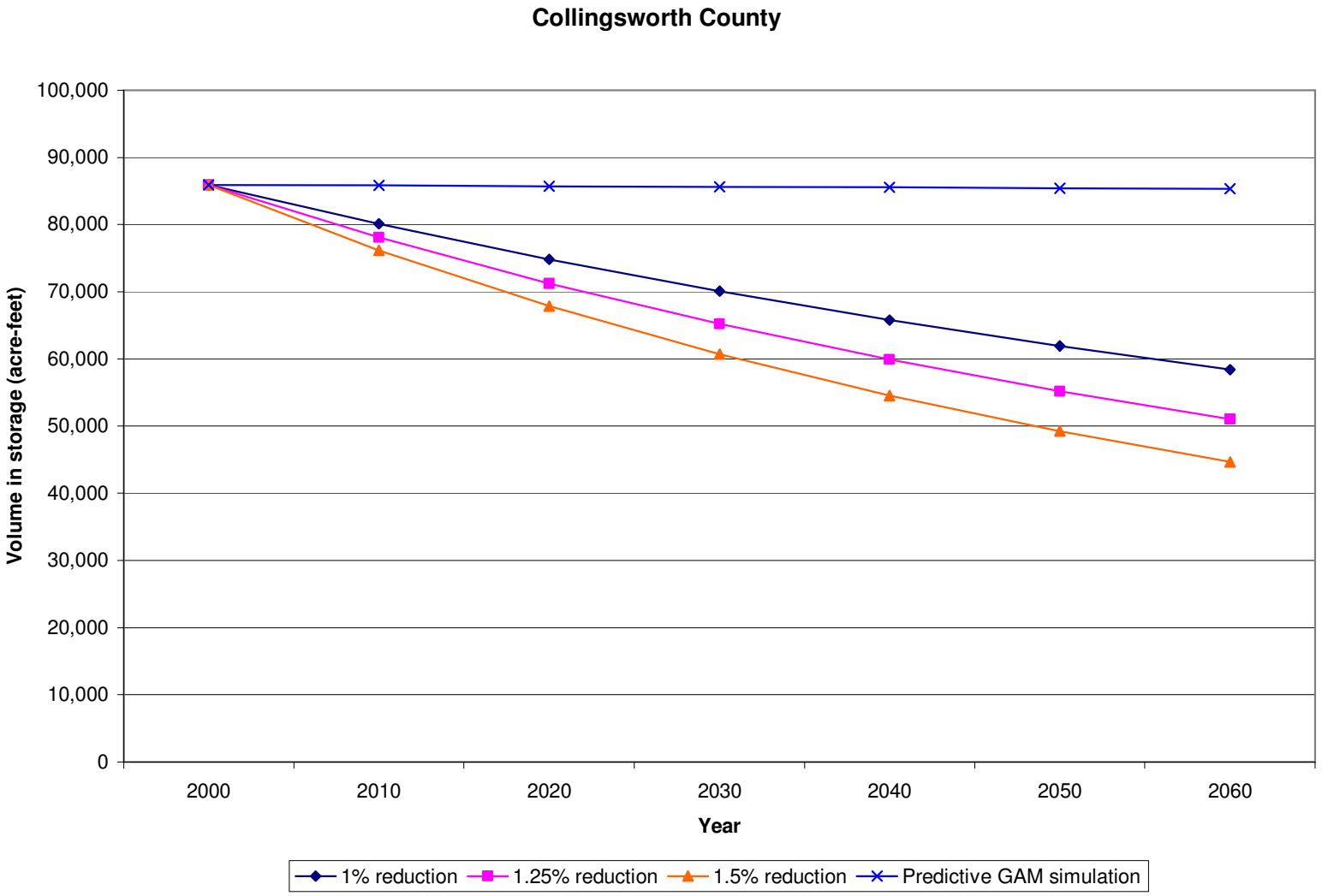


**Figure 3. Results of storage reduction analysis of the Ogallala Aquifer in Collingsworth County.**

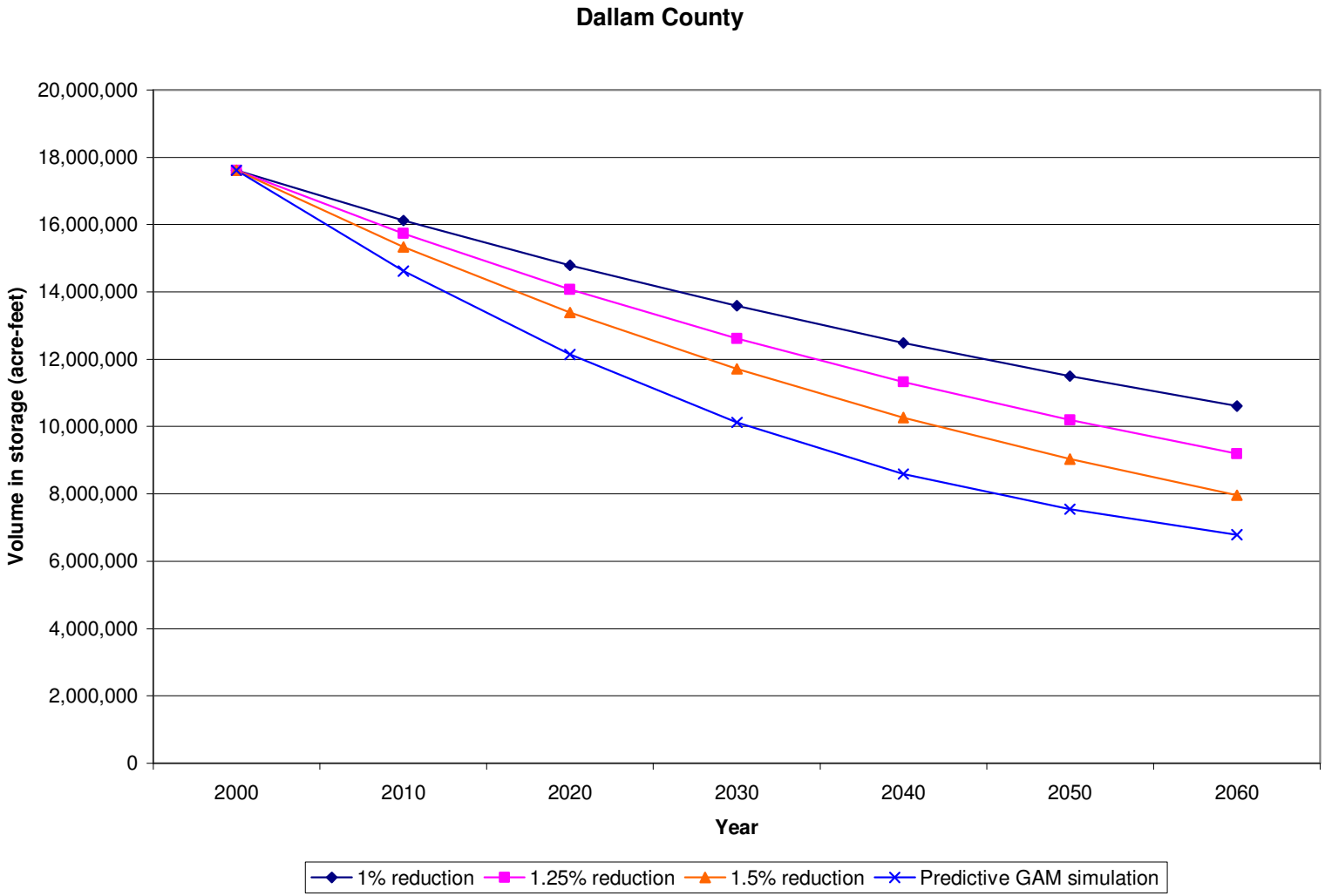


**Figure 4. Results of storage reduction analysis of the Ogallala Aquifer in Dallam County.**

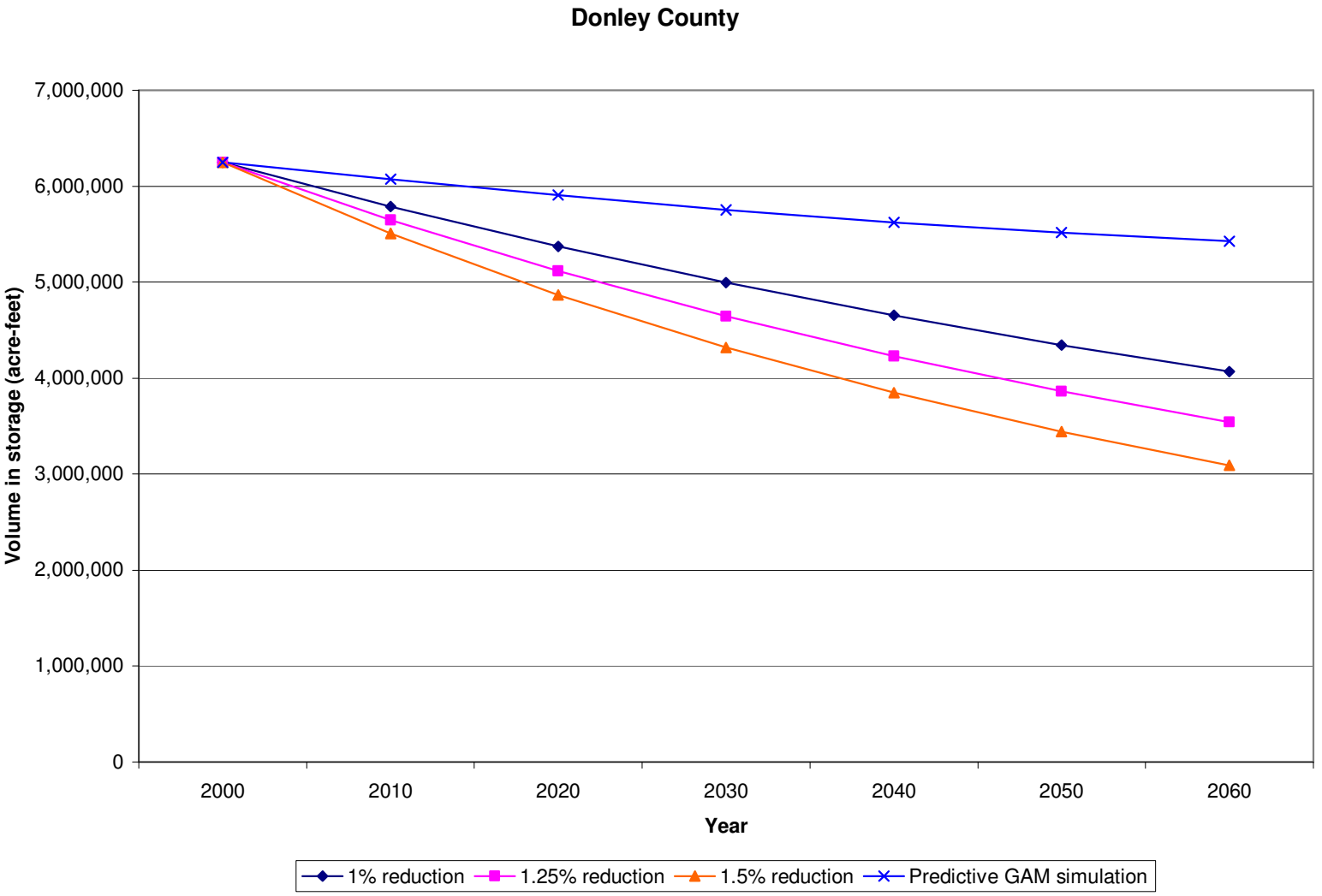


**Figure 5. Results of storage reduction analysis of the Ogallala Aquifer in Donley County.**

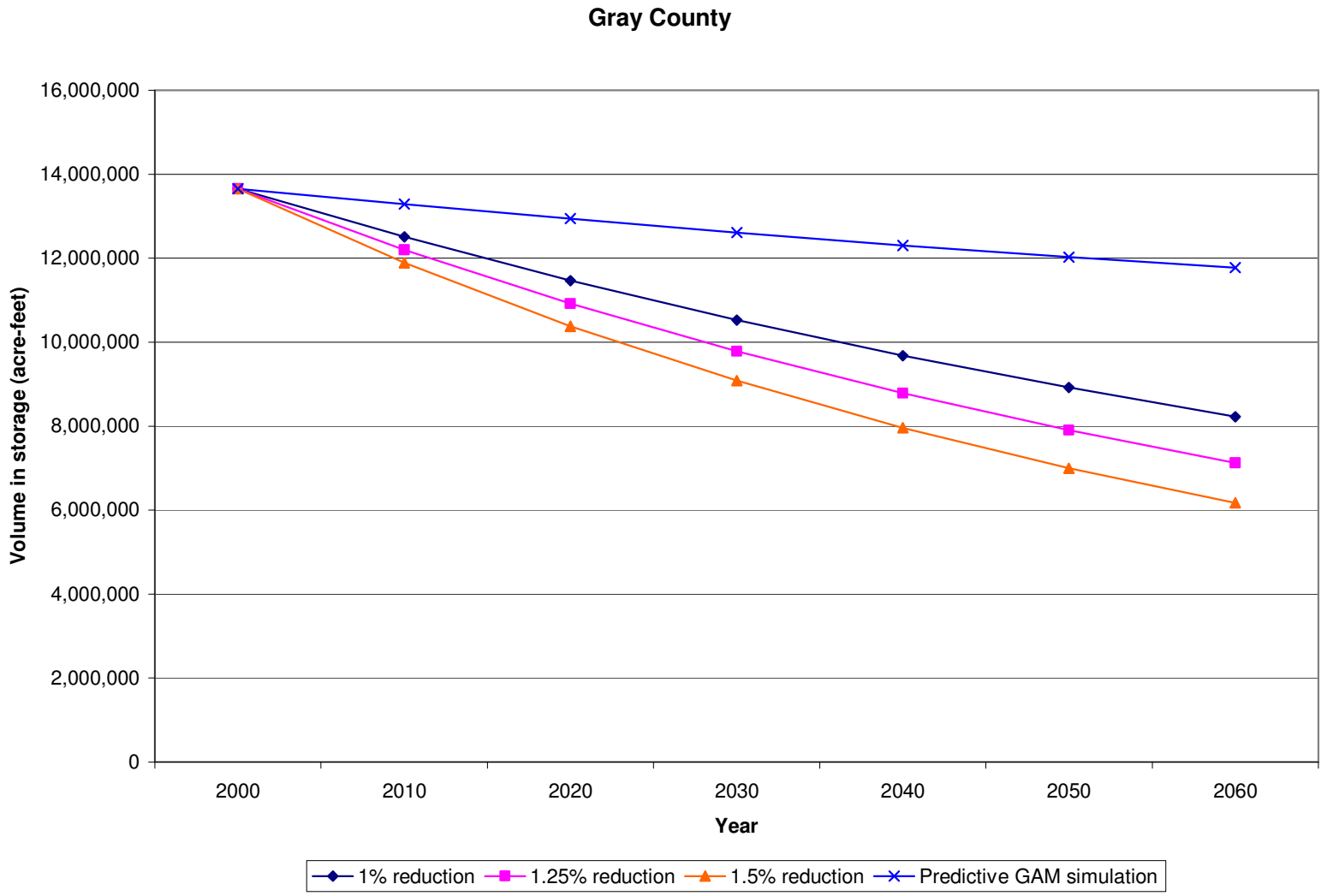


**Figure 6. Results of storage reduction analysis of the Ogallala Aquifer in Gray County.**

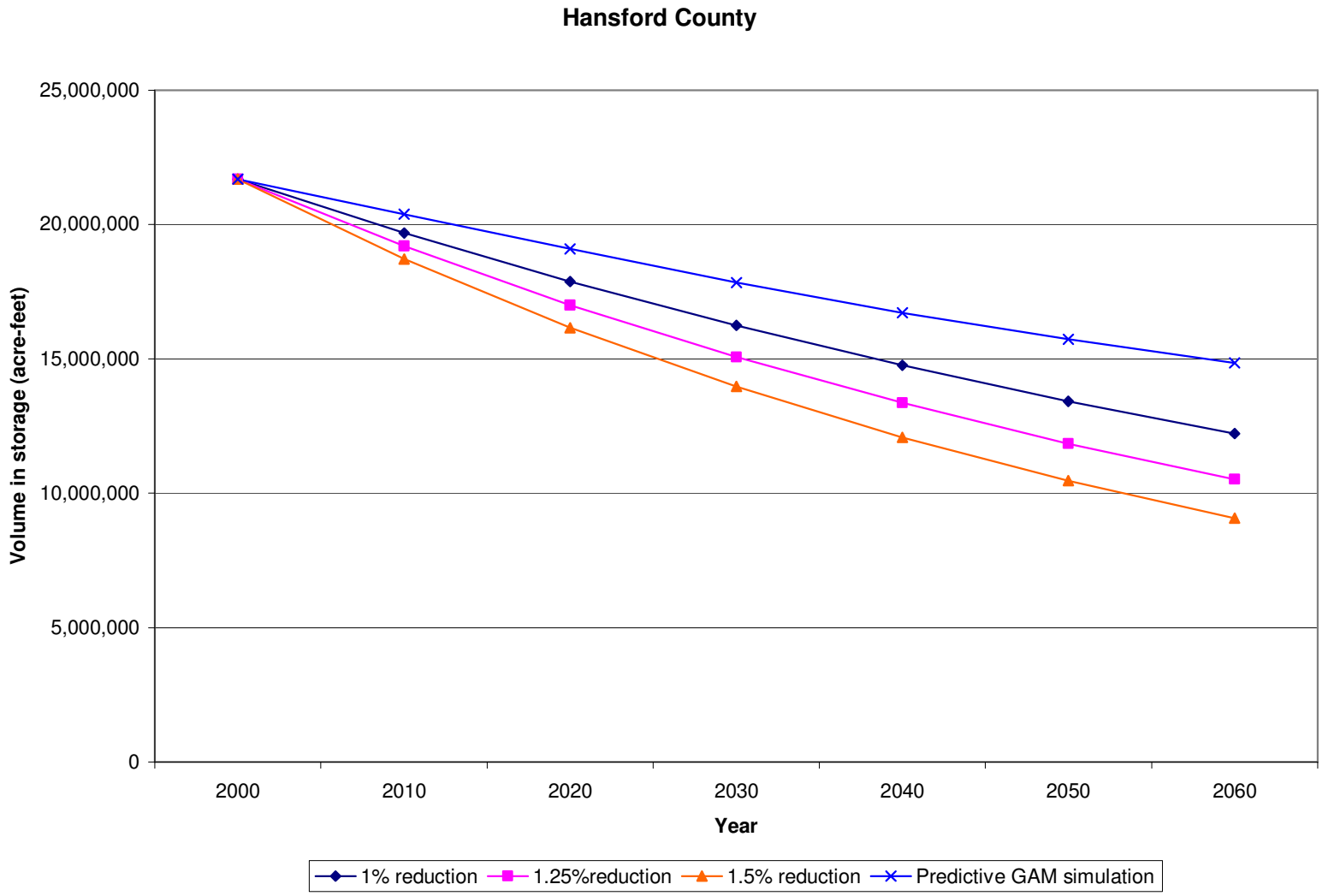


**Figure 7. Results of storage reduction analysis of the Ogallala Aquifer in Hansford County.**

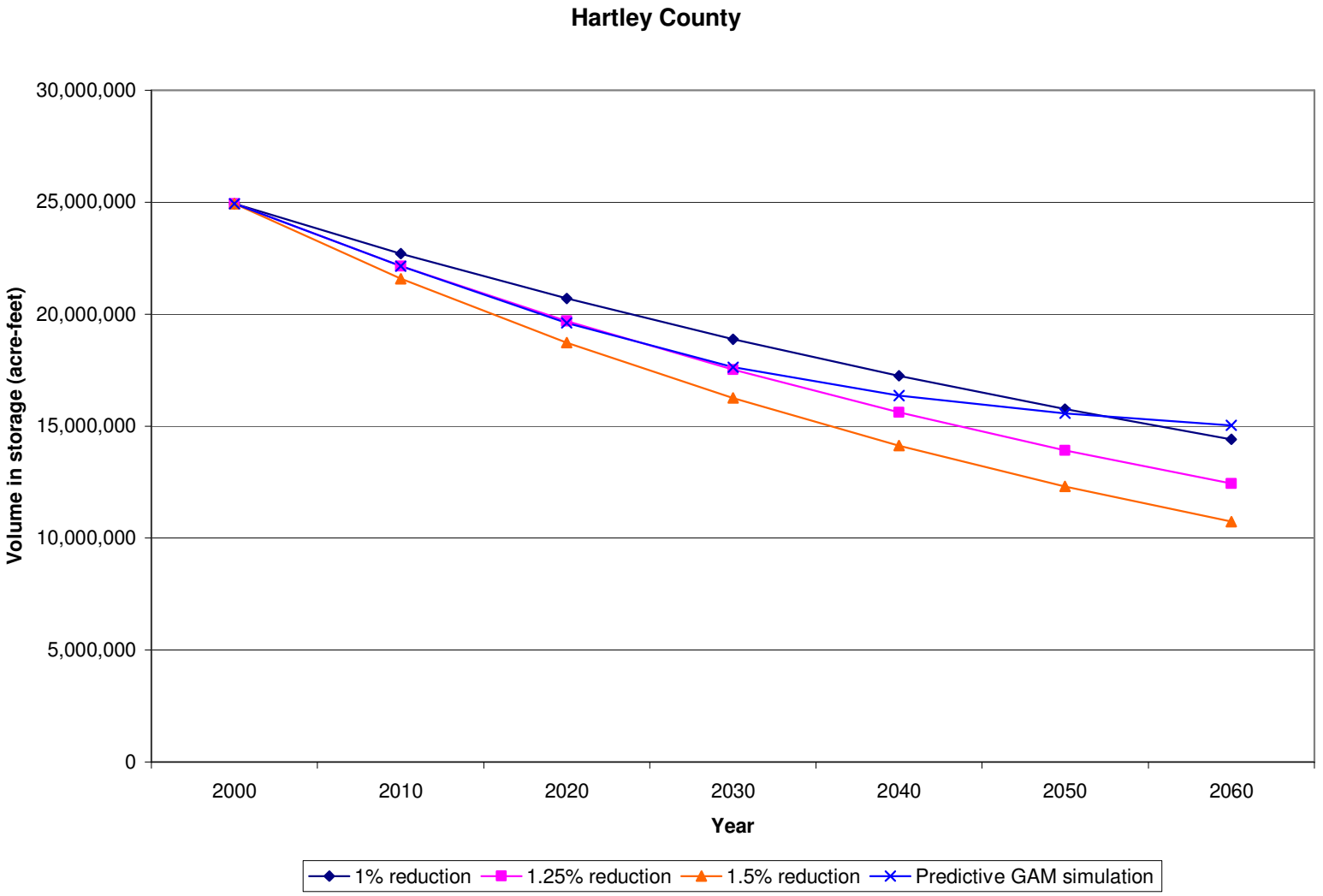


**Figure 8. Results of storage reduction analysis of the Ogallala Aquifer in Hartley County.**

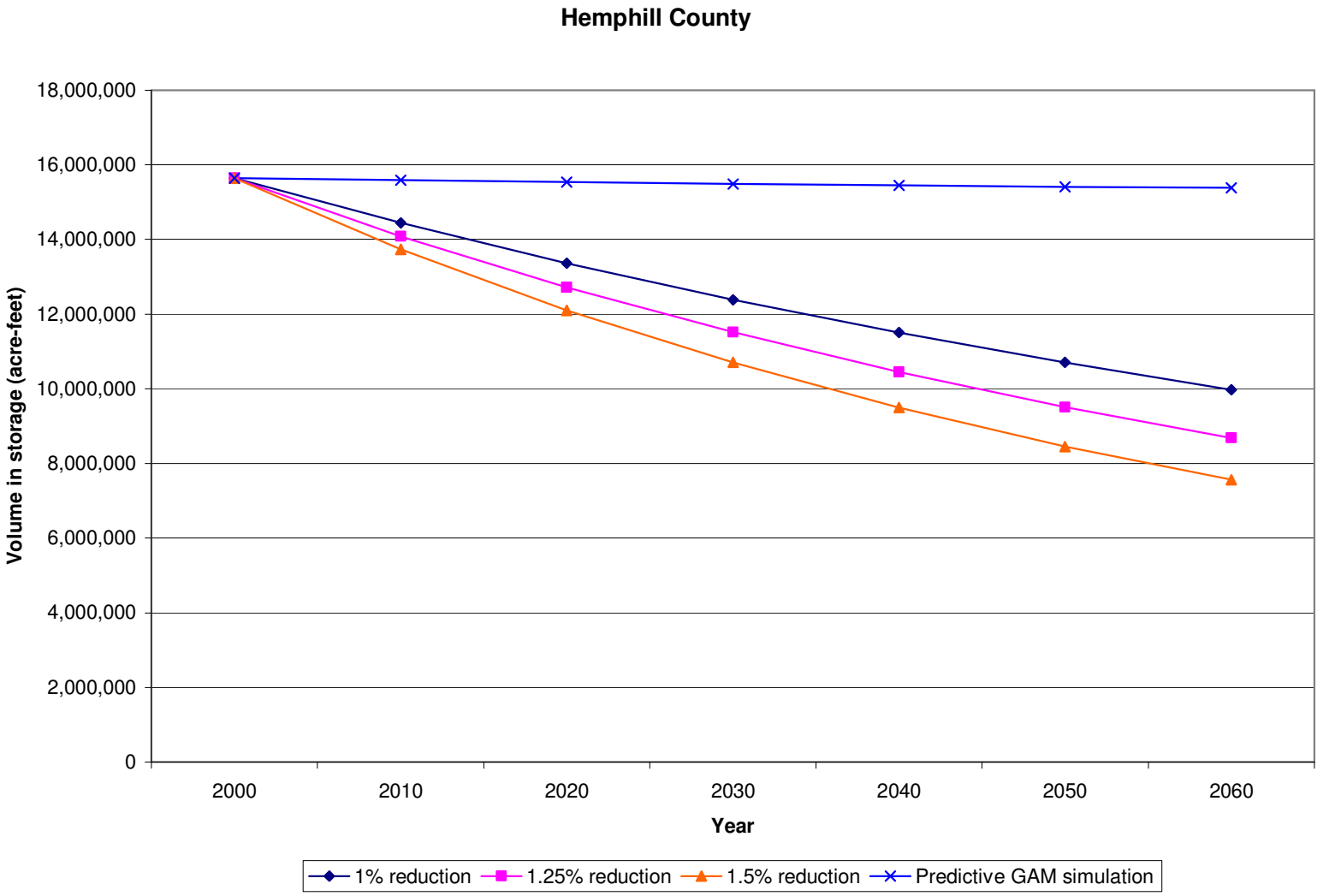


**Figure 9. Results of storage reduction analysis of the Ogallala Aquifer in Hemphill County.**

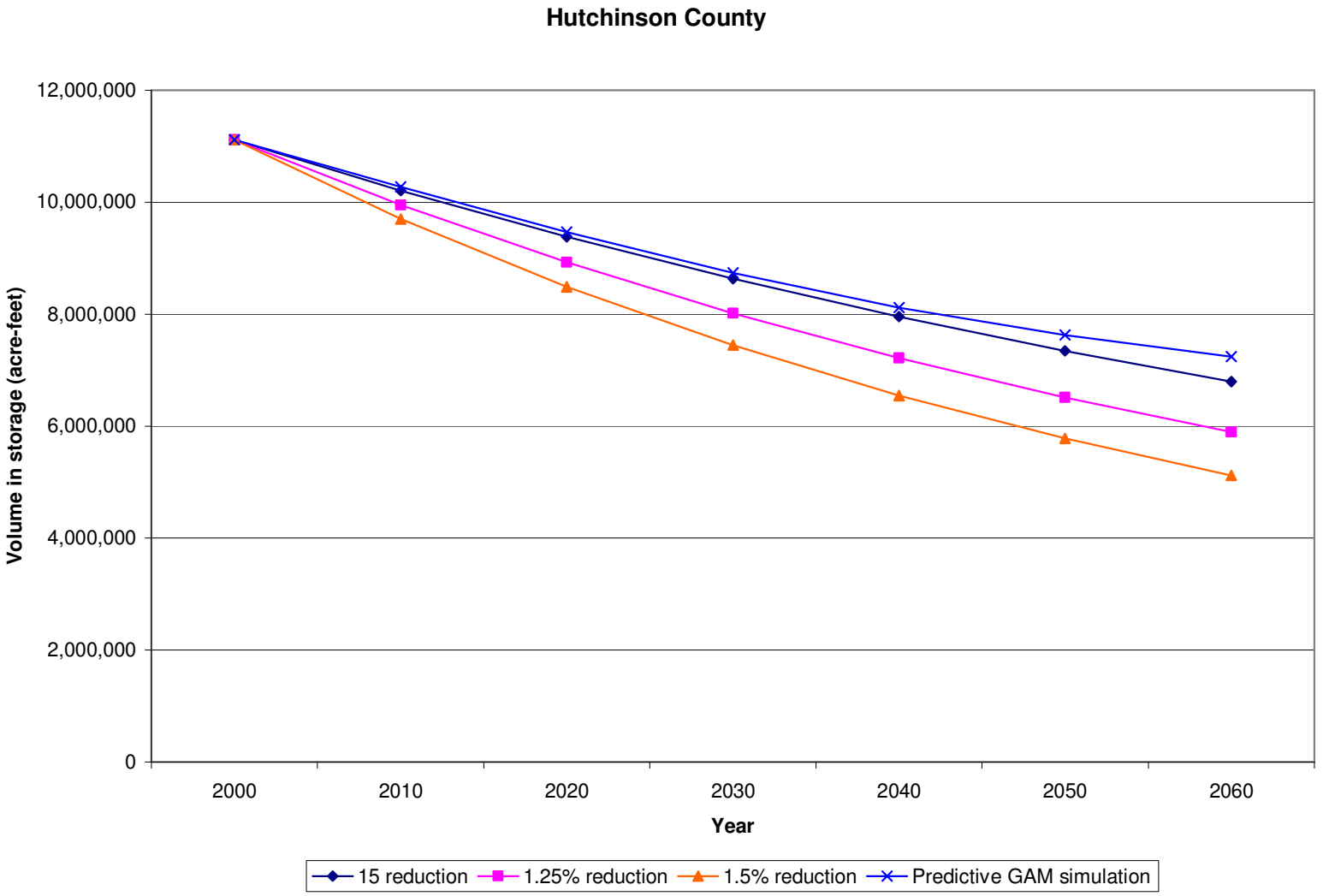


**Figure 10. Results of storage reduction analysis of the Ogallala Aquifer in Hutchinson County.**

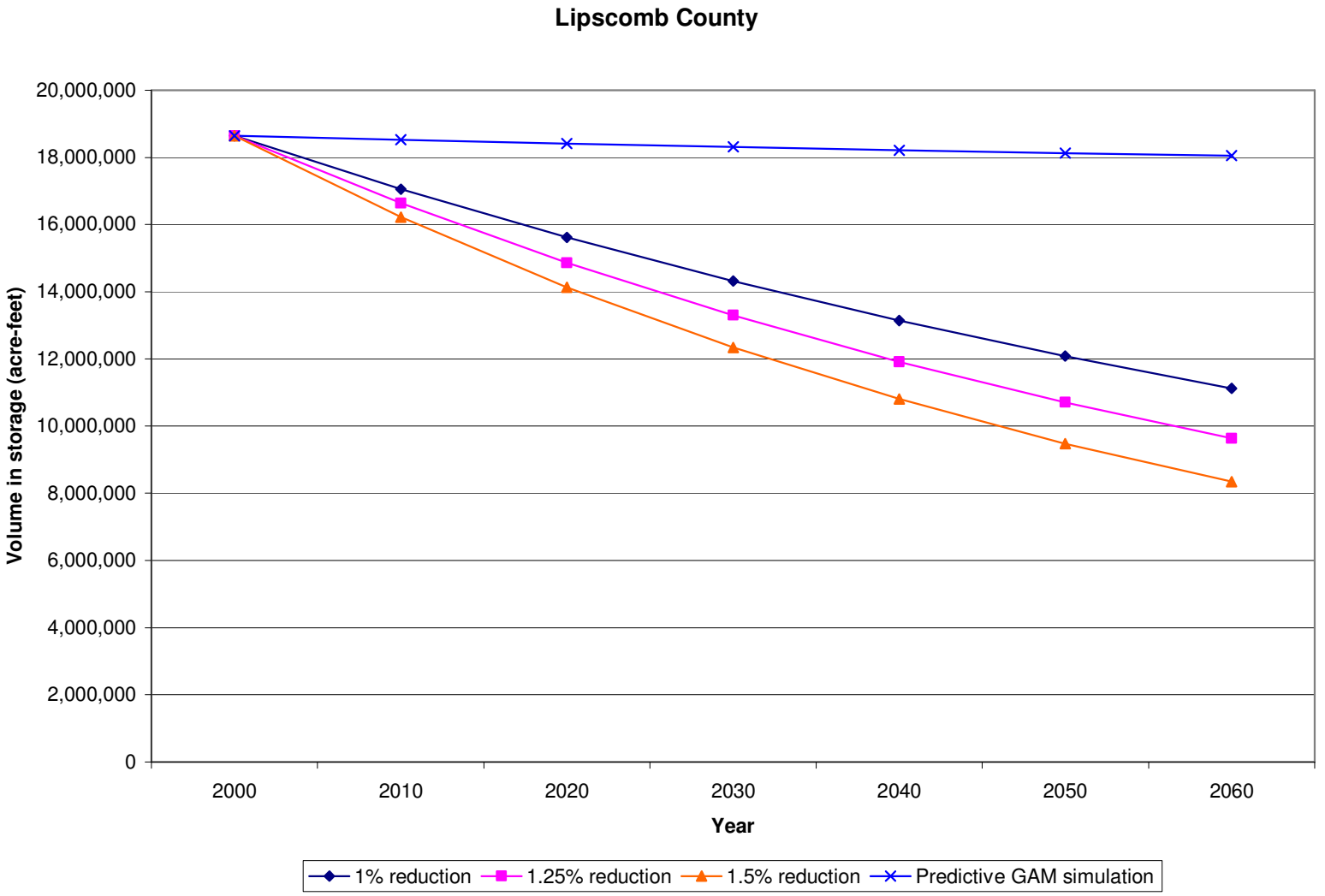


**Figure 11. Results of storage reduction analysis of the Ogallala Aquifer in Lipscomb County.**

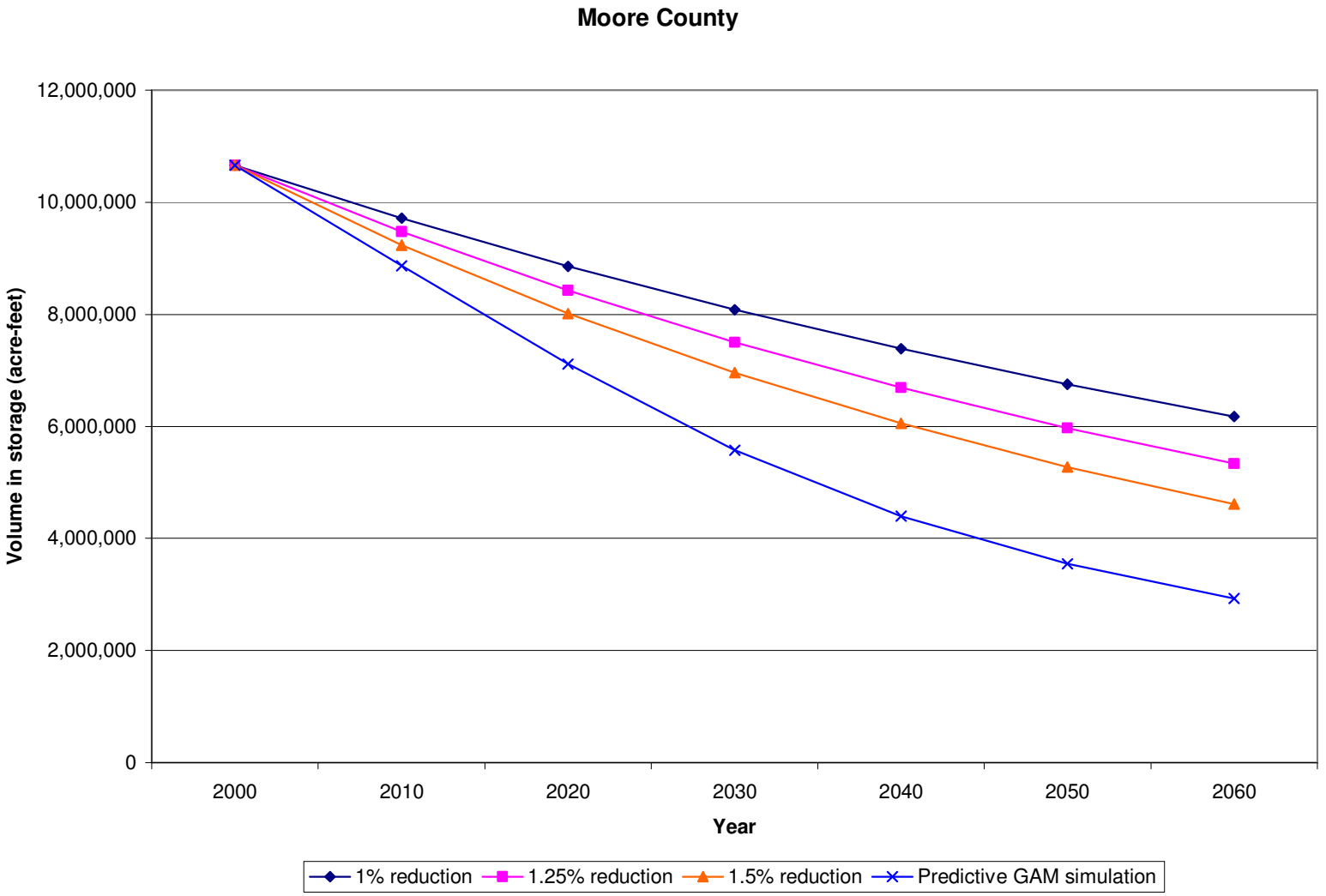


**Figure 12. Results of storage reduction analysis of the Ogallala Aquifer in Moore County.**

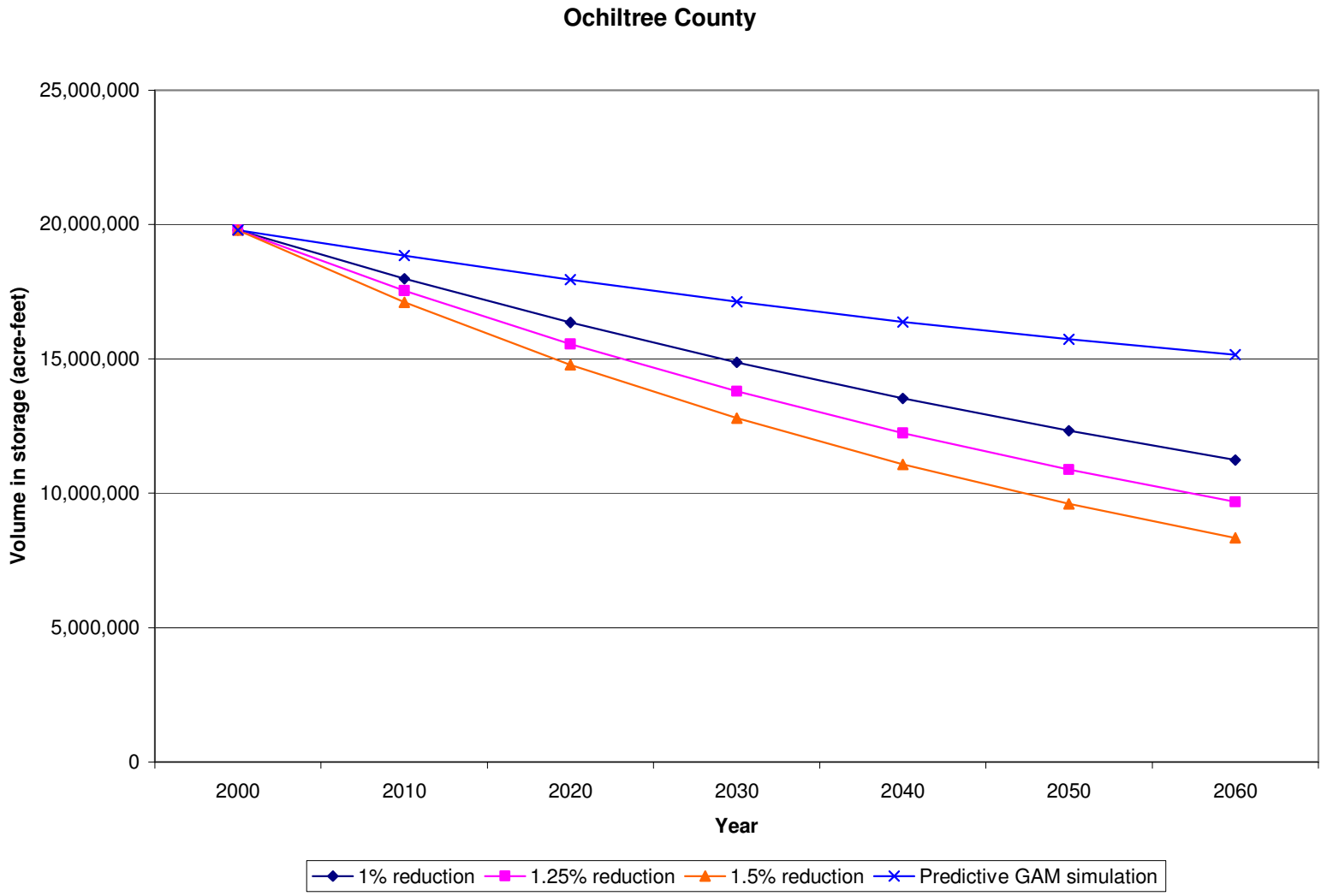


**Figure 13. Results of storage reduction analysis of the Ogallala Aquifer in Ochiltree County.**

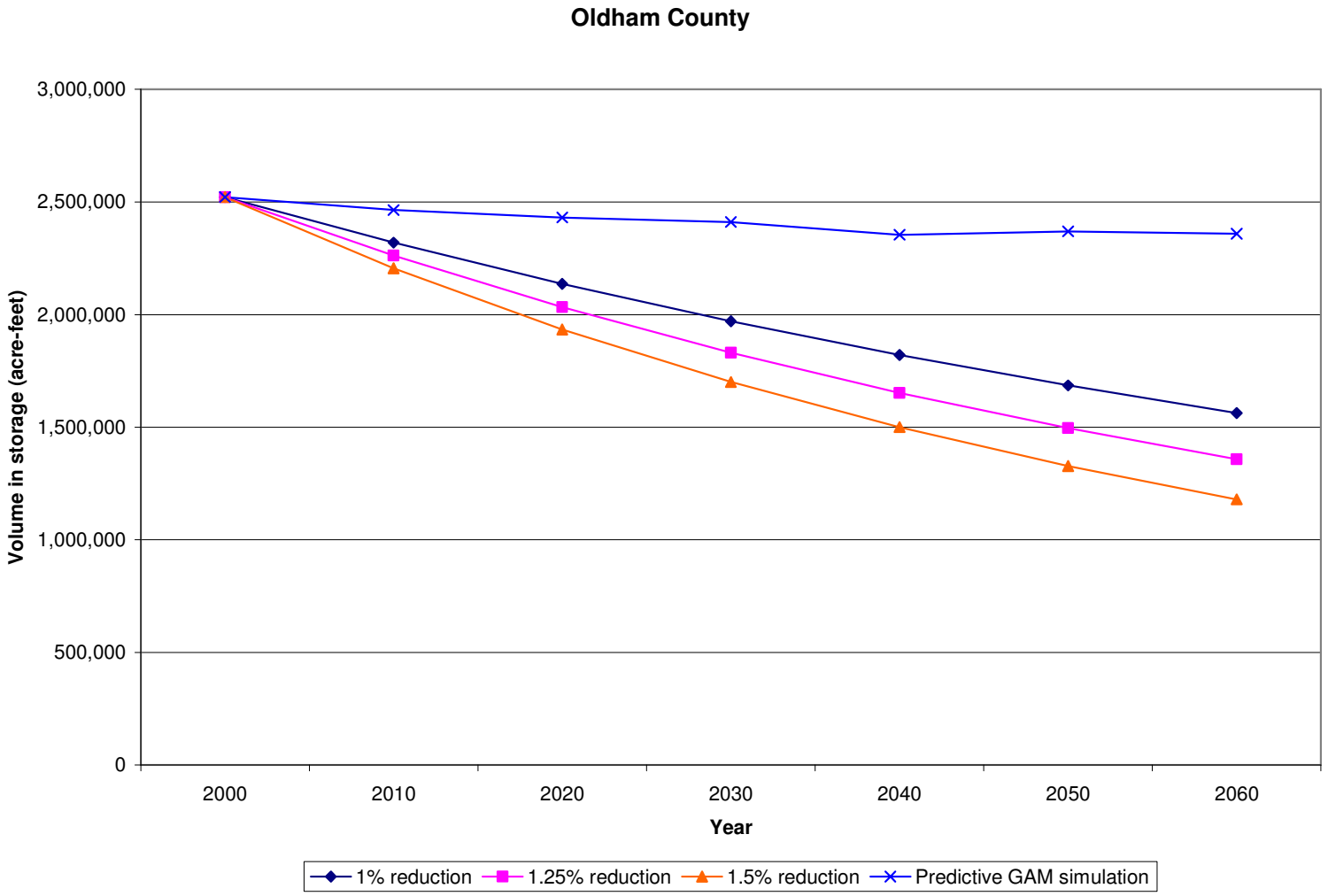


**Figure 14. Results of storage reduction analysis of the Ogallala Aquifer in Oldham County.**

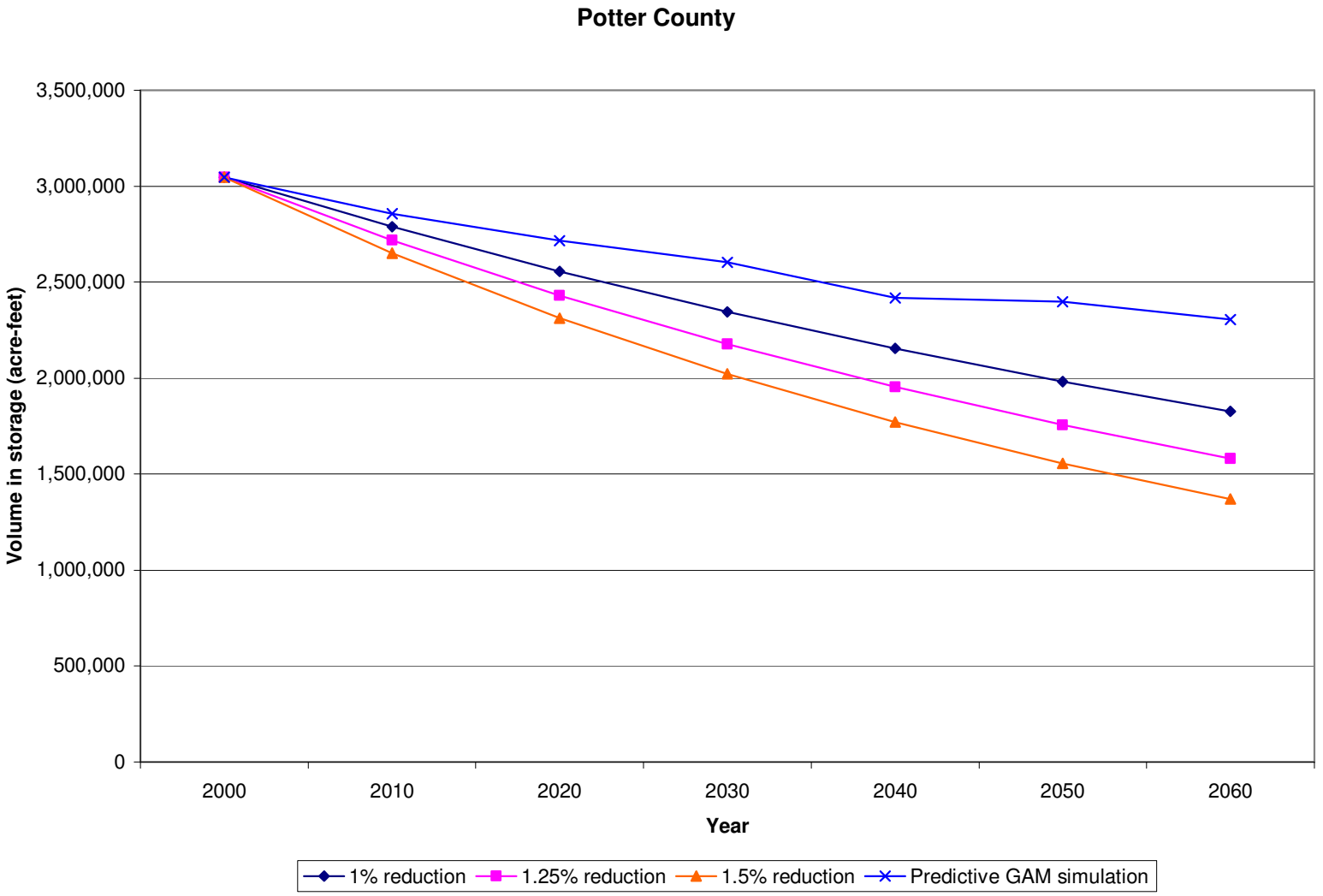


**Figure 15. Results of storage reduction analysis of the Ogallala Aquifer in Potter County.**

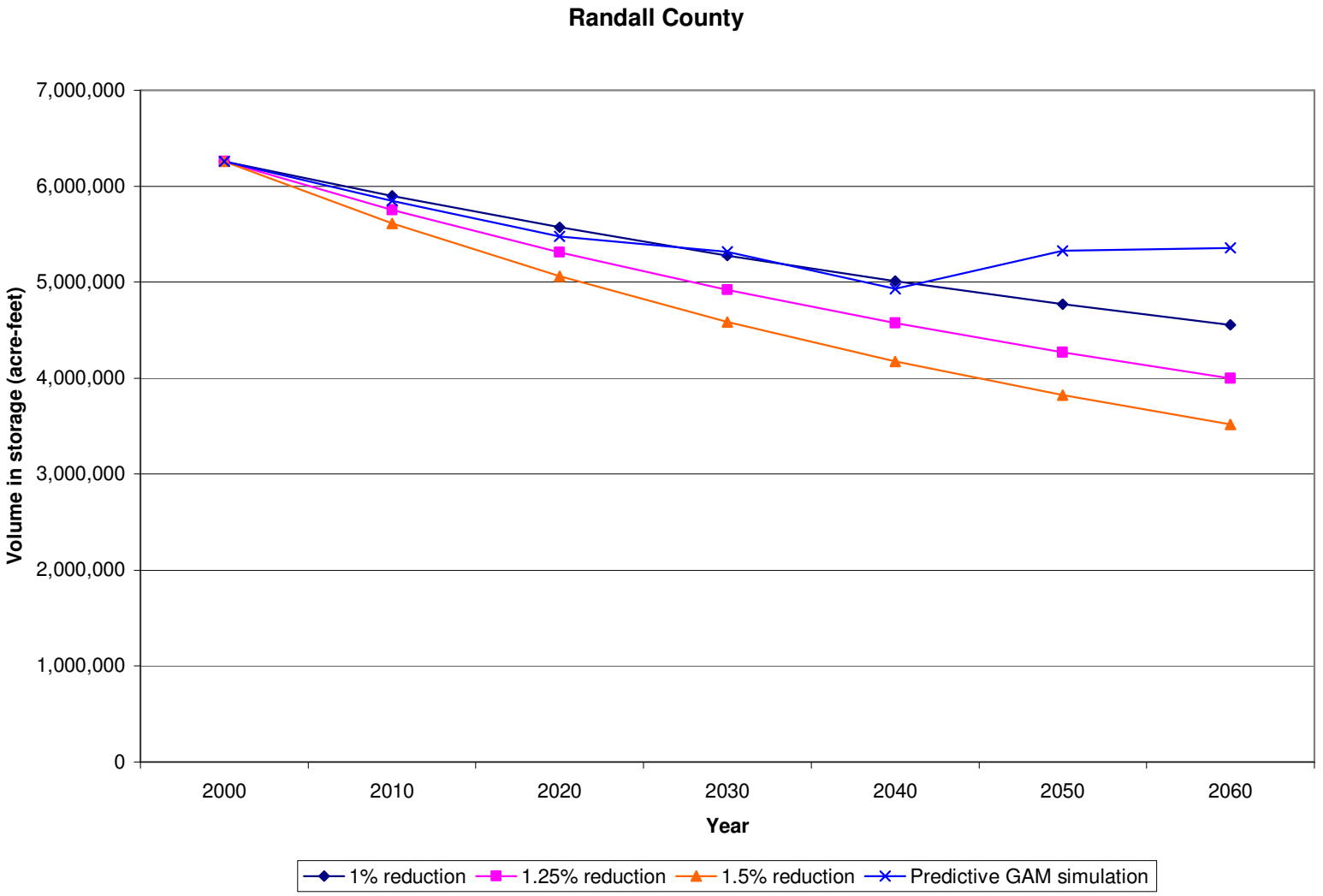


**Figure 16. Results of storage reduction analysis of the Ogallala Aquifer in Randall County.**

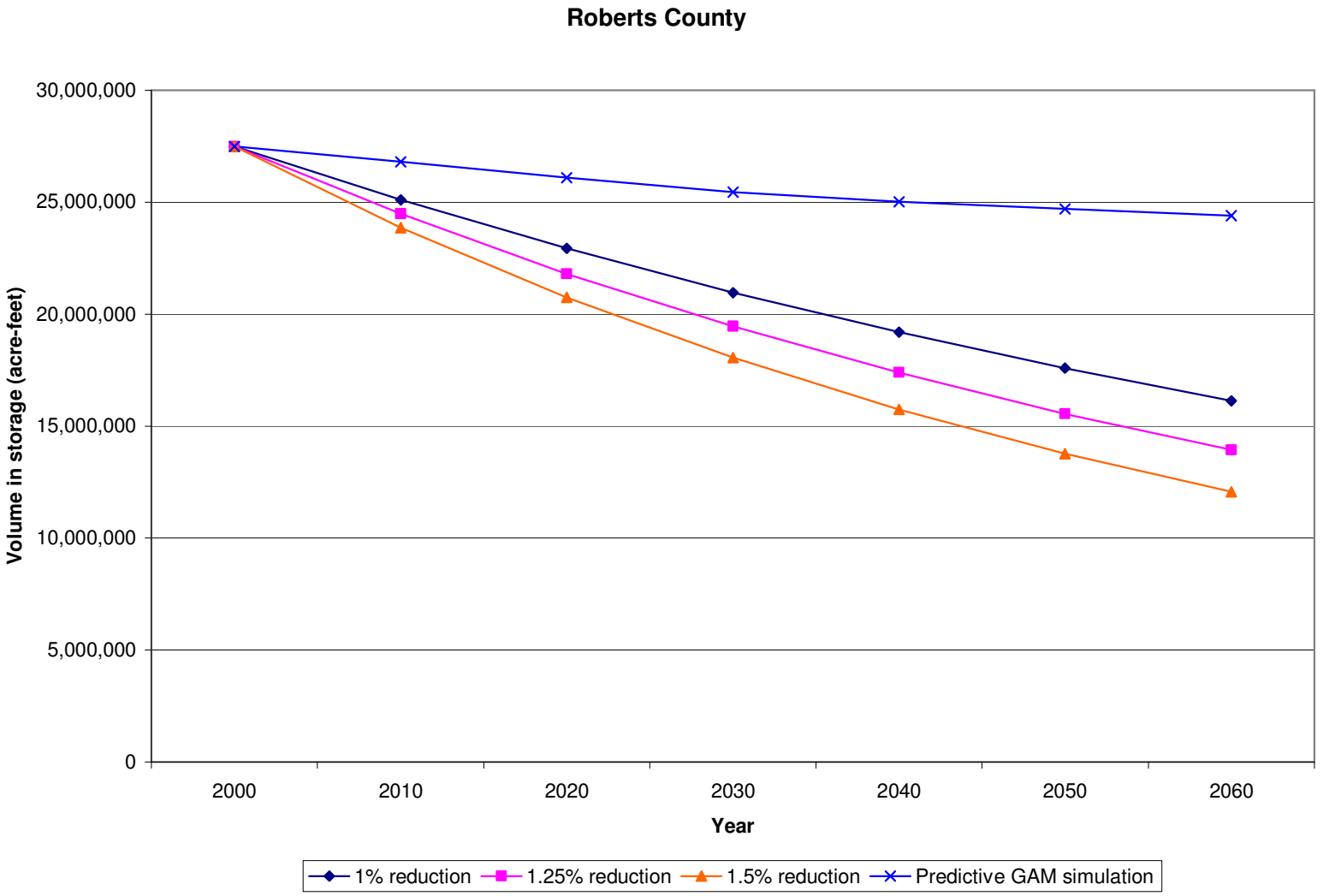


**Figure 17. Results of storage reduction analysis of the Ogallala Aquifer in Roberts County.**

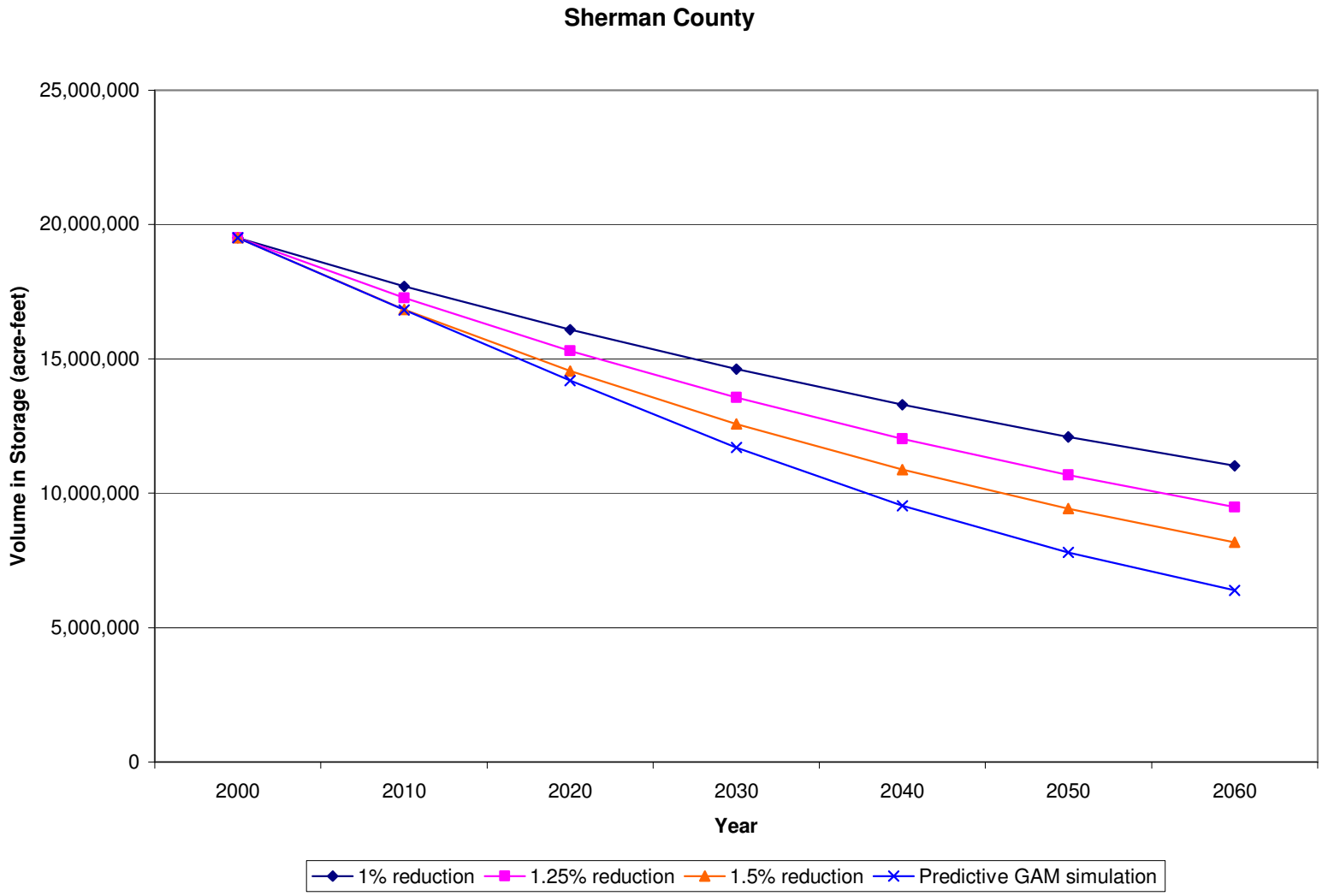


**Figure 18. Results of storage reduction analysis of the Ogallala Aquifer in Sherman County.**

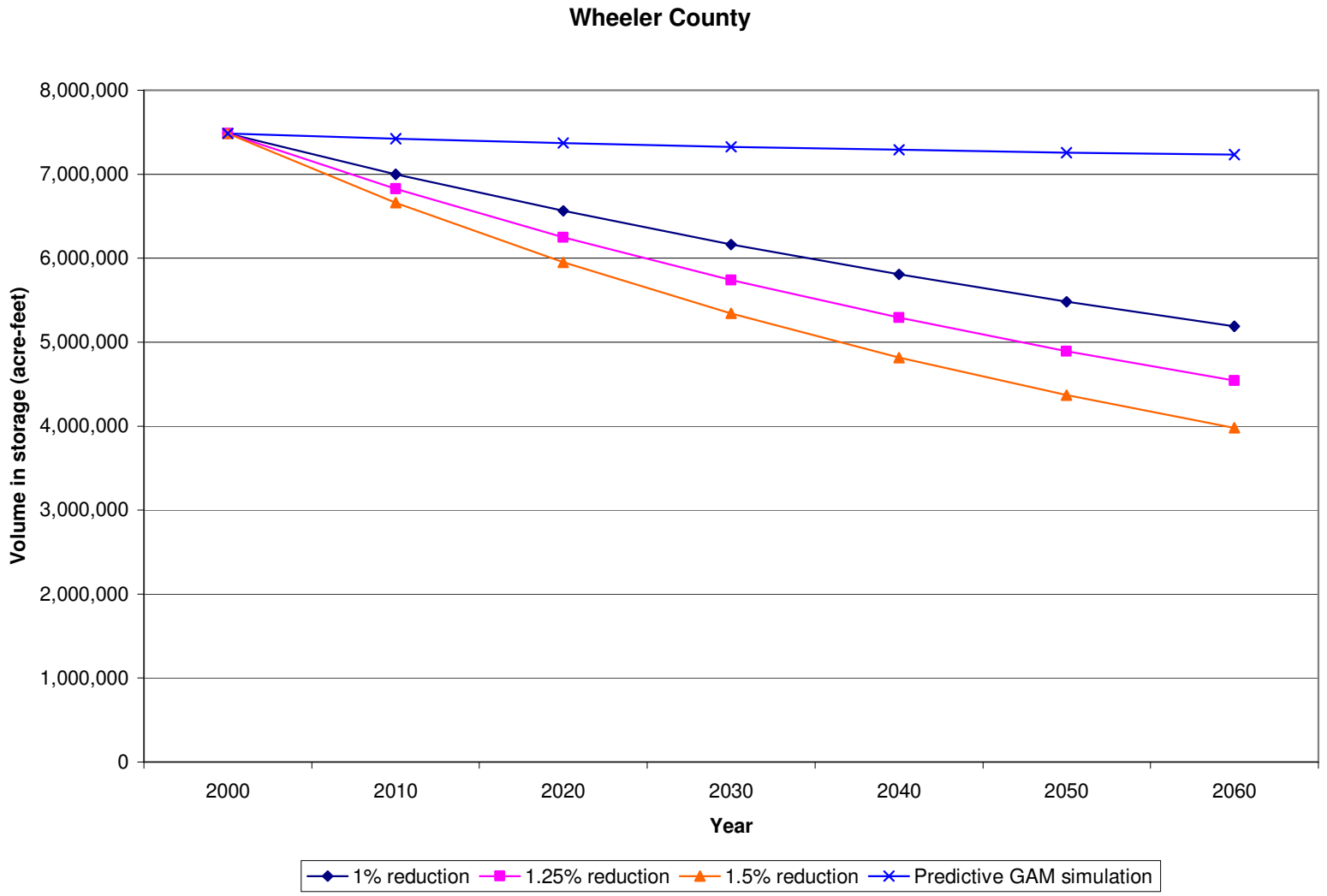


**Figure 19. Results of storage reduction analysis of the Ogallala Aquifer in Wheeler County.**