RELATIONSHIPS BETWEEN SKID NUMBERS, PAVING MATERIALS AND MIX DESIGN, AND ACCUMULATED TRAFFIC

by

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(The opinions, findings, and conclusions expressed in this report are those of the authors and not necessarily those of the sponsoring agencies.)

Virginia Highway & Transportation Research Council
(A Cooperative Organization Sponsored Jointly by the Virginia Department of Highways and Transportation and the University of Virginia)

In Cooperation with the U. S. Department of Transportation
Federal Highway Administration

June 1977
VHTRC 77-R57

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ABSTRACT

The objectives of this study were to determine the periods of time over which materials used in pavement surfaces provide adequate skid resistance and to classify various aggregate sources on the basis of the skid resistance qualities of the materials they produce. The objectives were achieved by evaluating the relationship between skid numbers from the Department's skid resistance survey program and various traffic volume measurements.

As expected, skid resistance was found to be related to traffic volumes. It appears that total accumulated traffic volume and accumulated truck traffic volume both relate well to the skid resistance potential of aggregates. The skid resistance potential as related to accumulated traffic volumes of aggregates from various sources varies, but in most cases it is good; i.e., it remains above an SN_{40} of 40 for accumulated truck volumes in excess of 3 million. Only limestone aggregates utilized in sprinkle mixes were rated poor ($SN_{40} < 30$ for accumulated truck traffic of 3 million).

It is recommended that a continuing study be undertaken by the Materials Division to utilize survey skid data for aggregate sources as was done in this project. Rankings in this report should, of course, be utilized as initial information for the Materials Division program. It is further recommended that the use of aggregates be judged on the basis of the ranking for the source and in consideration of the SN_{40} needs outlined in the report. Since most aggregates are rated "good", very little restriction in aggregate use would occur. Also, it is felt that "poor" and marginally rated aggregates could be utilized in situations where high skid resistance is needed, provided projected accumulated truck traffic volumes for the life of the mix indicate that sufficiently high SN_{40} values would be maintained.

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INTRODUCTION

One of the greatest concerns of those persons having the responsibility for providing safe levels of skid resistance on highways is the estimation of the levels that can or should prevail over the life of the pavement. Untold effort has been expended in devising laboratory methods for making predeterminations of these levels. Some successes have been achieved, but the persons involved are far from being satisfied. Additionally, all agree that the only completely valid means of evaluating the skid resistance characteristics of materials and mixes is to test roadways in service.

One way of accomplishing in-service evaluations would be to place many test sections of roadway and observe them over the years. This approach would be quite time-consuming and would not produce results for years. A more immediately productive means, and the one used in this project, is to analyze pavement surface data relating to materials in use in existing pavement mixtures, skid numbers obtained at 40 mph in a routine survey testing program, and accumulated traffic volumes. Most of the data needed for this type of evaluation were for interstate highways in Virginia accessible from the Virginia Department of Highways and Transportation automated files. Traffic volume data were extracted from the Department's annual reports on the average daily traffic volumes on interstate, arterial, and primary routes.

While this scheme does not provide a means for evaluating a new material, it does provide for evaluating and categorizing the materials and mixes now in service. These materials and mixes will, of course, be used for the large majority of future pavement surfaces in Virginia.

OBJECTIVE AND SCOPE

The objective of this study was to determine the periods of time over which materials used in pavement surfaces provide adequate skid resistance by evaluating the relationship between skid numbers from the Department's skid resistance survey program and various traffic volume measurements, and to classify various aggregate sources on the basis of the skid resistance qualities of the materials they produce.

The study was limited to survey skid data on hand when the analysis was begun, which include data for the entire interstate system and a small portion of the primary system. In the survey skid program, tests are run at only 40 mph, and only with treaded tires. Therefore, since tests at multiple test speeds with both treaded and bald tires are needed to provide a clear understanding of texture effects, these tests provided little information on the macrotexture of the pavement tested, which is an important factor in skid resistance. Consequently, since only the survey skid data were available, it should be understood that this study did not consider changes in skid resistance that may result from changes in macrotexture. Instead, the attempt was to evaluate specific aggregates, irrespective of surface textures. The only distinction made with respect to surface type is that between bituminous and portland cement concrete (PCC) surfaces. Also, with regard to materials, only the coarse aggregate of bituminous mixtures and the sand of portlane cement concrete surfaces were considered. The analysis was further limited to sites in which aggregate source sections matched traffic volume sections, since it was quite difficult to distinguish which traffic volume sections the individual skid tests were performed on; i.e., data from aggregate source sections which contained more than one traffic volume section were discarded. Further, since the authors did not visit the sites to determine the condition of the pavement surfaces, but merely analyzed data from the files, all surface treatment and slurry seal sites were eliminated because there was no way to identify those sites on which the surface treatment aggregate had been lost or the slurry seals had been worn through.

Analyses were made on the basis of accumulated traffic volume, accumulated truck traffic, average yearly truck traffic and average number of vehicles daily. The accumulated volume analysis seemed to provide the best means of predicting the potential skid life of a pavement and it was, therefore, selected as the prime analysis for this report.

Finally, the scope of the project was limited to sites for which sufficient information was available for the analysis. Consequently, only 580 sites and 56 sources of aggregates were included. For a clear understanding of the potential skid numbers of all the aggregates in Virginia, a continuing effort will be needed. In this continuing effort, refinements in the methodology should be incorporated especially with respect to inspection of sites with low values.

DATA ANALYSIS

For the analysis data were initially gathered by aggregate source on the basis of surface mix sections, i.e., sections of a pavement surface for which mix type and material sources as well as age were constant. As indicated above, for bituminous mixes the coarse aggregate source was given attention, which for PCC sections the fine aggregate source (sand) was considered important. An example of the data as gathered by surface mix sections is shown in Table 1* for the most common bituminous concrete surface mix (S-5)(1) with the coarse aggregate source being General Crushed Stone in Doswell. Data gathered in addition to the location of the surface mix section included:

1. The type of highway (2, 4, or 6 lanes) so as to permit the summation of traffic volumes by lane.
2. The lane in which skid tests were taken.
3. The age of the surface mix to the nearest 0.5 year at the time of skid testing.

*All tables and figures follow text.

4. The month and year skid tests were made.
5. The average SN_{40} for each surface mix section lane and the number of skid tests the average was based on (N).
6. The most current average vehicles daily (AVD).
7. Accumulated traffic volume figures for passenger cars and trucks (all classifications of trucks) and buses.

Data for the surface mix sections were further summarized by sites (Table 2) where each site represents one or more surface mix sections for which age, accumulated volumes, current AVD, and mix and material characteristics were consistent. For instance, the second and third surface mix sections shown in Table 1 (Route 17, Middlesex County) were combined as one site since the age, mix characteristics, and traffic volume data were the same for both sections. Average SN_{40} values were determined for sites on the basis of weighted averages of the average surface mix section SN_{40} values (weighted on the basis of N for each surface mix section). A site was not considered unless the average SN_{40} value represented at least two tests, and generally the site sample size (N) was 5 or more tests. In addition, accumulated total lane volume, accumulated truck volume, average trucks yearly (ATY), AVD, and the date of skid testing were determined for each site.

Assignment of Accumulated Traffic Volumes

Traffic volume data were obtained from the Department's published traffic volume information. (2) The volume data are reported annually by traffic volume sections in terms of AVD and represent the total AVD for that section of roadway represented by the traffic volume sections. Thus, the AVD values shown in Tables 1 and 2 represent the total AVD for the roadway containing the surface mix section or site. However, in determining accumulated volumes, one-half of the yearly AVD figures were used assuming a 50-50 distribution in volumes by direction, and therefore, the accumulated volume values shown in Table 1 for the surface mix sections represent the accumulated volumes for one direction of travel. For instance, for the first surface mix section (NBTL of Route 17, Essex County) the accumulated traffic volumes are for the northbound direction only.

Further modifications had to be made to the accumulated volumes values as data were summarized by site to correctly reflect the accumulated volume for the traffic lane tested. Again considering the first surface mix section shown in Table 1, the skid tests are for the NBTL of a 4-lane divided highway. Thus, something less than 100% of the northbound accumulated volumes must be assigned to the traffic lane to correctly reflect the accumulated traffic lane volumes. In this project, assignment of volumes by lane were made on the basis of the current AVD as shown in Table 3. These assignments were determined based on some limited field data collected as part of this study and shown in Figures 1 and 2, and supported by recent studies in Kentucky and Georgia. (3,4) As shown in Table 3 and Figures 1 and 2 the percentage of total traffic in the outside lane on 4-lane divided highways decreases as the AVD increases, but truck traffic in the outside lane remains fairly constant at about 85%. For 6-lane divided highways, only limited data were obtained, and these represent only AVD counts between approximately 35,000 and 55,000. Generally, the proportions by lane appeared to remain fairly constant in the AVD ranges for which data were obtained, with the possible exception of truck traffic between the outside and center lane (Figure 2). Thus, it was considered appropriate to utilize the constant proportions by lane for 6-lane divided highways as shown in Table 3, especially since almost all sites on highways of this type were within the indicated AVD range.

Relationship of SN_{40} to Volume Measurements

As indicated previously, the major objective of this study was to determine and classify the skid resistance qualities of various material sources used in Virginia on the basis of the relationship between SN_{40} and some measure of traffic volume. Four measures of traffic volume were evaluated: total accumulated volume, accumulated truck volume, ATY, and AVD. For each aggregate source, the SN_{40} was plotted against each of the four volume measurements for each site tested. Data were also summarized by aggregate type and plots were prepared for the summarized data. Figures 3-6 present the plots of summarized data for granite aggregates and limestone aggregate. Sprinkle mixes, in general, represent the extremes in terms of polishing, i. e., they represent the greatest loss in skid resistance with increases in traffic volume. The plots represent the average SN_{40} value for the volume value indicated.

As shown, accumulated total volume and accumulated trucks relate about equally well to SN_{40}; that is, the maximum disinction between the two aggregates and the minimum SN_{40} level attained for each method of volume measurement is about the same (Figures 3 and 4). Thus, it seems evident that most polishing is due to truck traffic, or that truck volumes are a good indication of total volumes, or both.

As indicated in Figure 5, the SN_{40} also relates to ATY, although there is some averaging effects such that the minimum SN_{40} values obtained in relating SN_{40} to accumulated volumes are not reached. No relationship was indicated between SN_{40} and AVD (Figure 6), which again shows the greater influence of truck traffic (Figure 5) on SN_{40} since a relatively small percentage of the AVD is truck traffic.

On the basis of the relationships discussed above, it was decided to rate the skid resistance potential of aggregate sources on the basis of accumulated truck traffic with the realization that accumulated total traffic may be as good a measure.

Evaluation of Aggregate Skid Resistance Potential by Source

To rate the skid resistance potential of aggregates, a minimum curve— a curve depicting the minimum SN_{40} levels for each accumulated truck volume value— was prepared for each source for which data were available. A minimum curve is shown in Figure 7 for General Crushed Stone of Doswell. Obviously, some judgement was exercised in determining the minimum curves, especially where apparently extreme, nonconsistent minimum points were found. Unusual or extreme conditions were noted so that by future site examinations it could be determined if the point should be included in developing the minimum curve or if the low SN_{40} value was the result of some non-aggregate factor such as flushing.

Once the minimum curve was developed the aggregate's skid resistance potential was rated as excellent, good, marginal, or poor, according to the system shown in Table 4. The rating was determined on the basis of the minimum SN_{40} level the curve would reach over the accumulated truck volume range of 0 - 3.0 million since, on the basis of the data obtained in the study, it appeared the minimum SN_{40} level would stabilize by 3.0 million accumulated truck volume. Thus, to illustrate, the aggregate from General Crushed Stone shown in Figure 7 could be rated good, since the minimum SN_{40} value determined by the curve is in the range 40 - 49. The SN_{40} values chosen for use in the rating system are based on minimum

SN_{40} guidelines determined for use in Virginia as reported in "Critique of Tentative Skid Resistance Guidelines". (5)

Table 5 presents the aggregate skid resistance ratings by source for coarse aggregates for bituminous mixes and fine aggregates for PCC mixtures. In Table 5, status refers to the confidence associated with the rating, and a tentative status may appear when either of the two situations listed below exist.

1. The minimum curve was determined on the basis of fewer than 15 points.
2. The minimum curve was determined on the basis of accumulated truck volumes for which no points were as great as 3.0 million accumulated volume.

Where a dash appears under status it indicates confidence in the rating. As indicated in Table 5, minimum curves are shown for aggregate sources for which data are given in Appendix Figures A-1 - A-48. With these curves, an evaluation can be made of minimum SN_{40} values at accumulated truck volumes less than 3.0 million. In this manner, predictions of accumulated truck volumes can be made, and marginal and poor aggregates can be used in situations where low accumulated truck volume predictions permit their use.

Table 5 includes ratings for most Virginia aggregate producers from which materials are used. For many producers no rating was made because no data were available. However, these sources were included in anticipation of a continuing rating system to be handled by the Materials Division. It is also anticipated that all sources, particularly those receiving tentative ratings, would be updated with additional data in the continuing evaluation system.

Finally, for several limestone sources the term "sprinkle" appears under status. Ratings of these sources were all on the basis of limestone sprinkle mixes, i.e., limestone mixes on which precoated polish resistant aggregate was sprinkled during construction. For many of these mixes, which are in the experimental stage, it is felt that much of the polish resistant aggregate was lost and the skid resistance values shown are indicative of limestone pavement. However, it is felt that sprinkle mixes, regardless of the limestone source or non-polishing sprinkle aggregate, must be evaluated on the basis of the minimum curve shown in Figure A-1 until additional data are available.

CONCLUSIONS AND RECOMMENDATIONS

As expected, the skid resistance potential of aggregate was found to be related to traffic volumes. On the basis of data obtained in this study it appears that total accumulated volume and accumulated truck volume are both good indicators of skid resistance potential. The skid resistance potential of aggregates from various sources varies as indicated in Table 5 and Figures A-1 through A-48, but in most cases it is good, i.e., it remains above an SN_{40} of 40 for accumulated truck volumes in excess of 3.0 million. Only limestone aggregates utilized in sprinkle mixes were rated poor ($SN_{40} < 30$ for accumulated truck traffic of 3.0 million).

It is recommended that a continuing study be undertaken by the Materials Division to utilize survey skid data for the purpose of ranking the skid resistance potential of aggregate sources as was done in this project. Rankings in this report should, of course, be utilized as initial information for the Materials Division program.

With regard to the utilization of the ranking data, it is recommended that use of aggregates be judged on the basis of the ranking for the source and in consideration of SN_{40} needs as outlined in Table 4. Since most aggregates are rated good, very little restriction in aggregate use would occur. Also, it is felt that aggregates rated poor could be utilized on low traffic volume roads provided projected accumulated truck volumes for the life of the mix indicate that sufficiently high SN_{40} values would exist. In most cases accumulated truck volumes could not exceed about 10.5 million. The use of aggregates rated poor would continue to be acceptable in blended mixes as presently allowed, but poor or marginally rated aggregates should not be used as the non-polishing aggregate in a blended or sprinkle mix.

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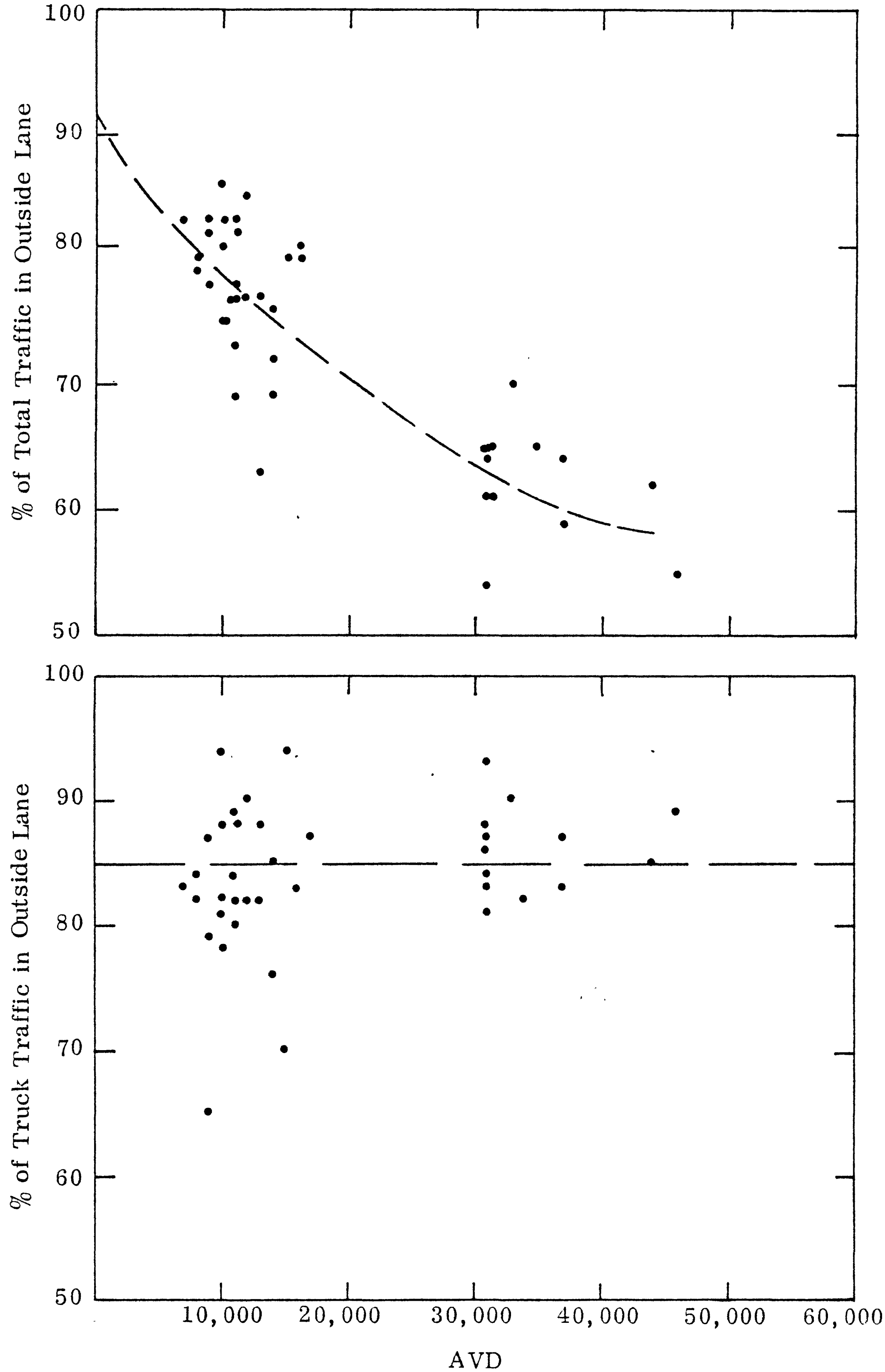

Figure 1. Lane distributions on 4-lane, divided highways.

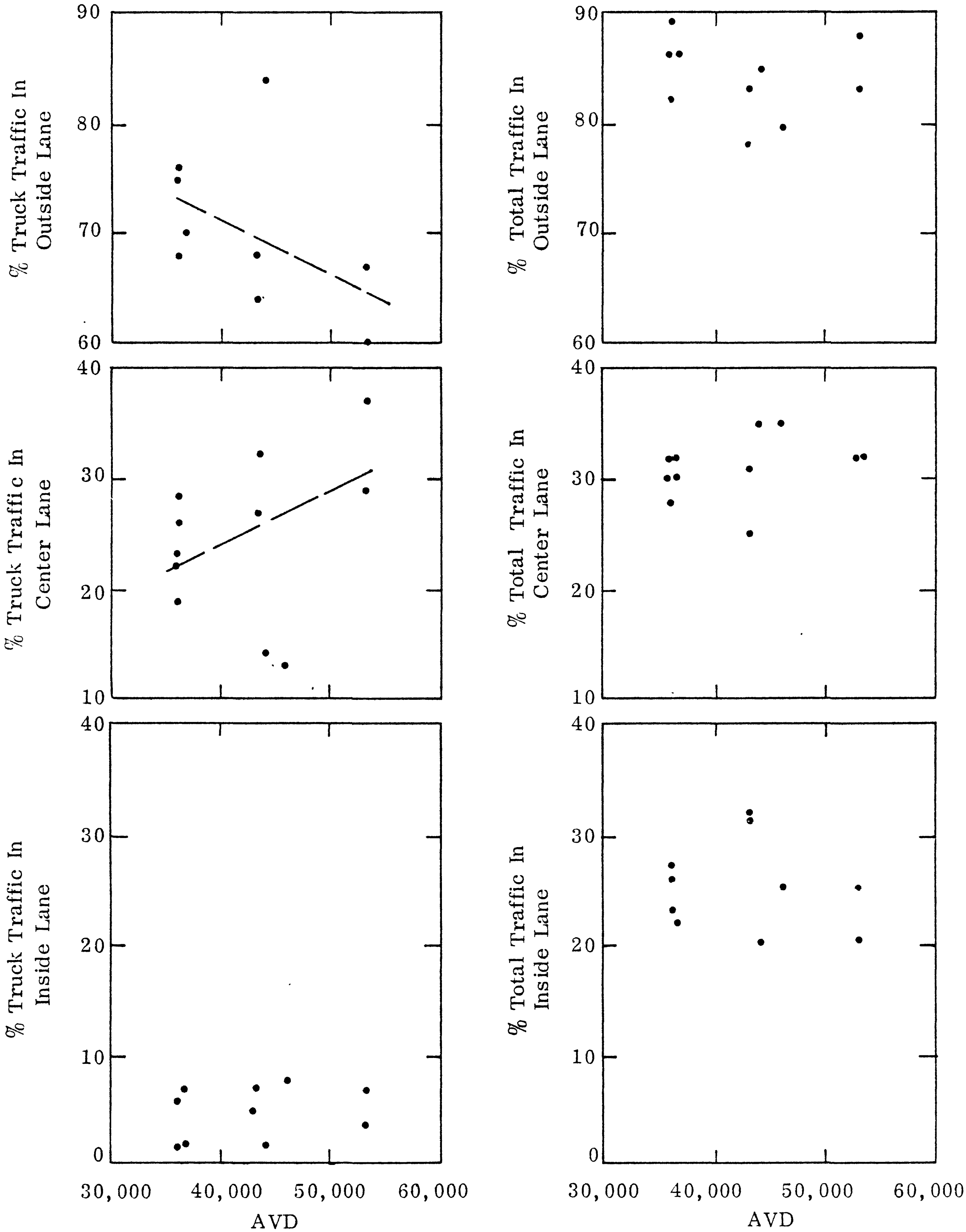

Figure 2. Lane distributions on 6-lane, divided highways.

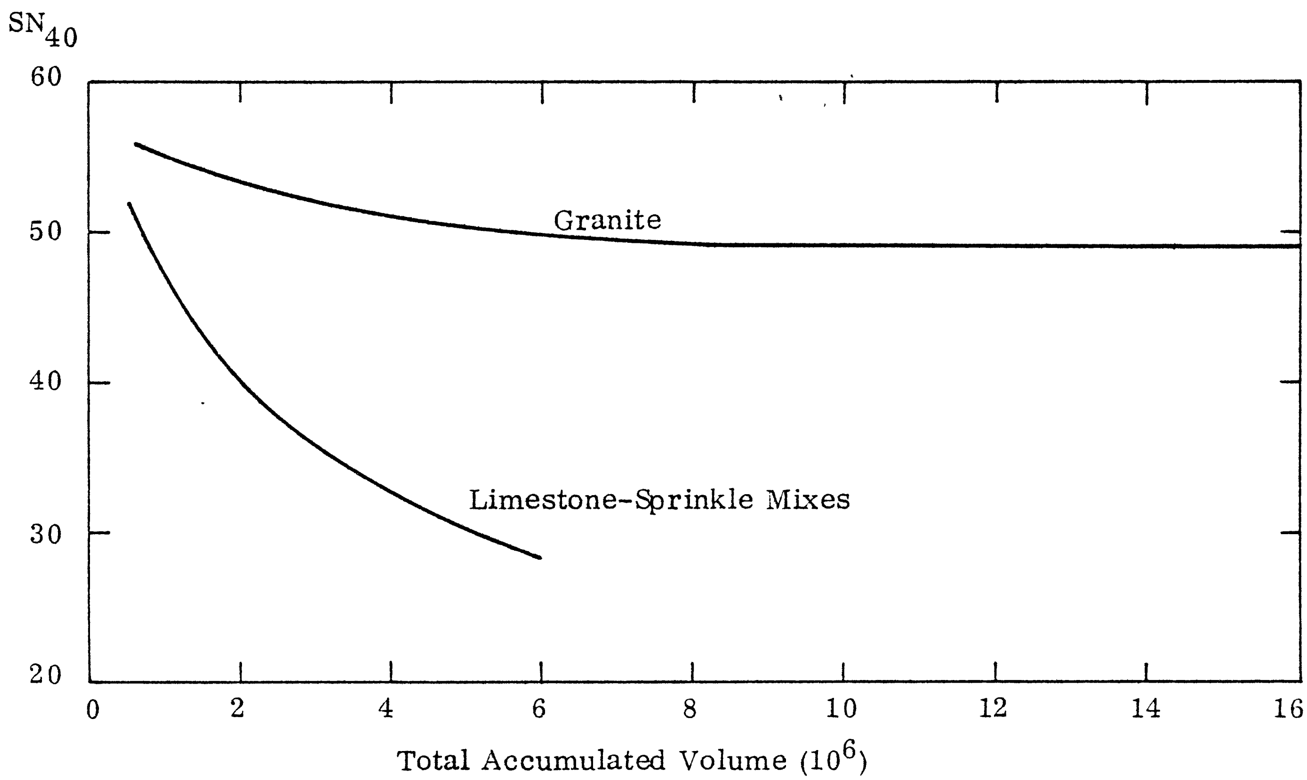

Figure 3. SN_{40} versus total accumulated volume.

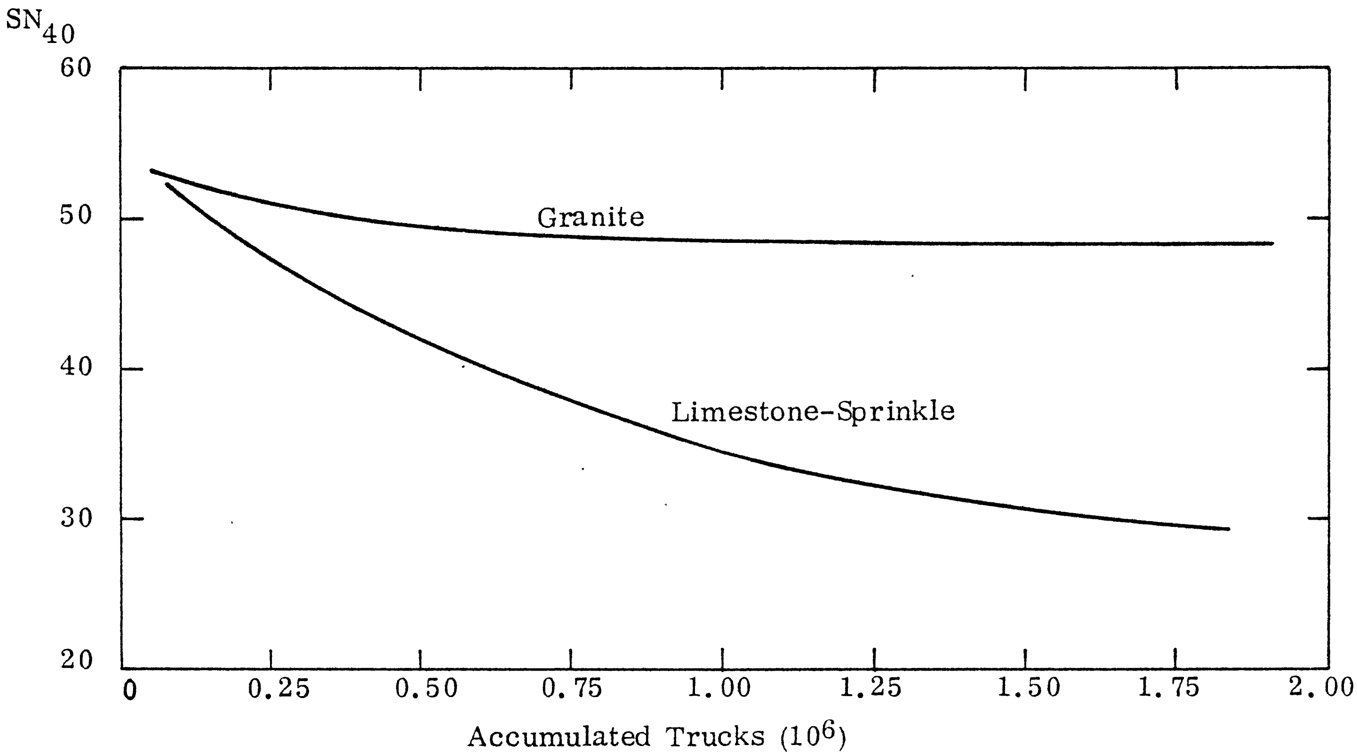

Figure 4. SN_{40} versus accumulated truck volume.

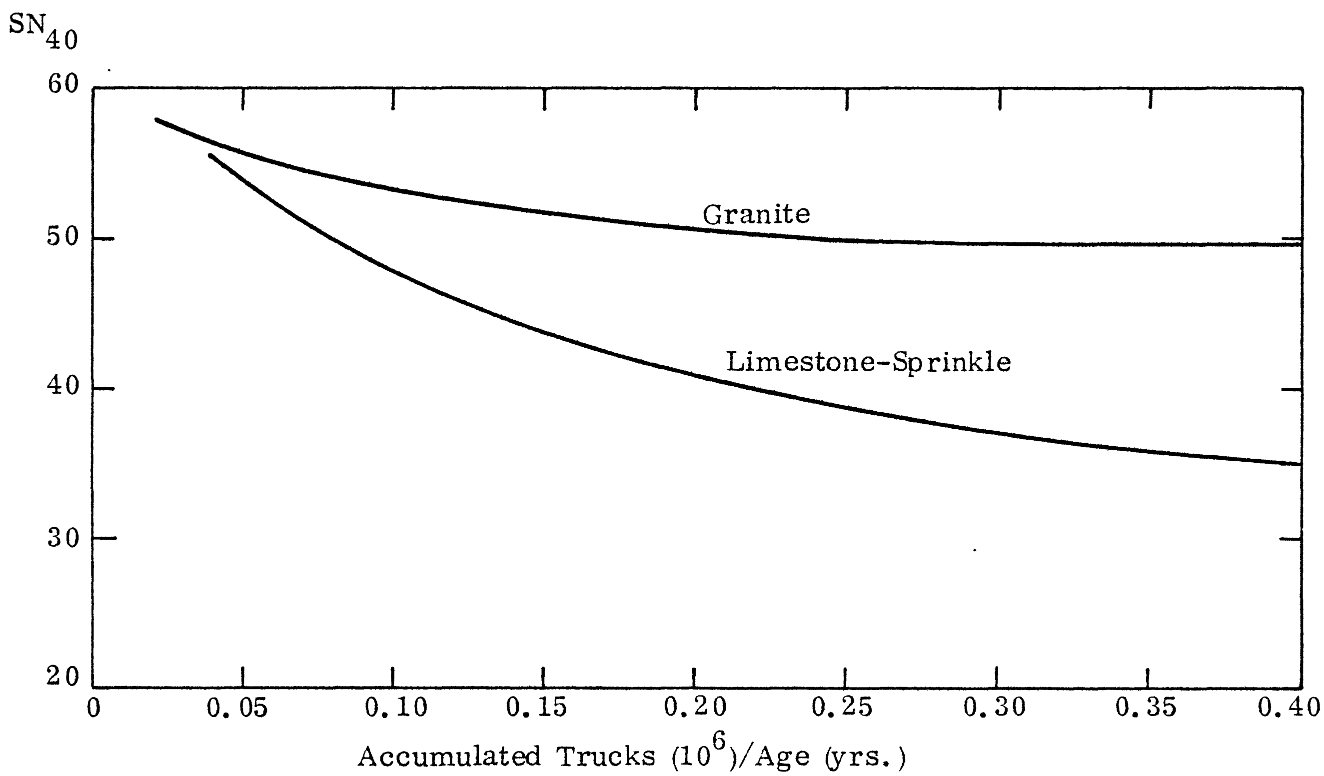

Figure 5. SN_{40} versus ATY

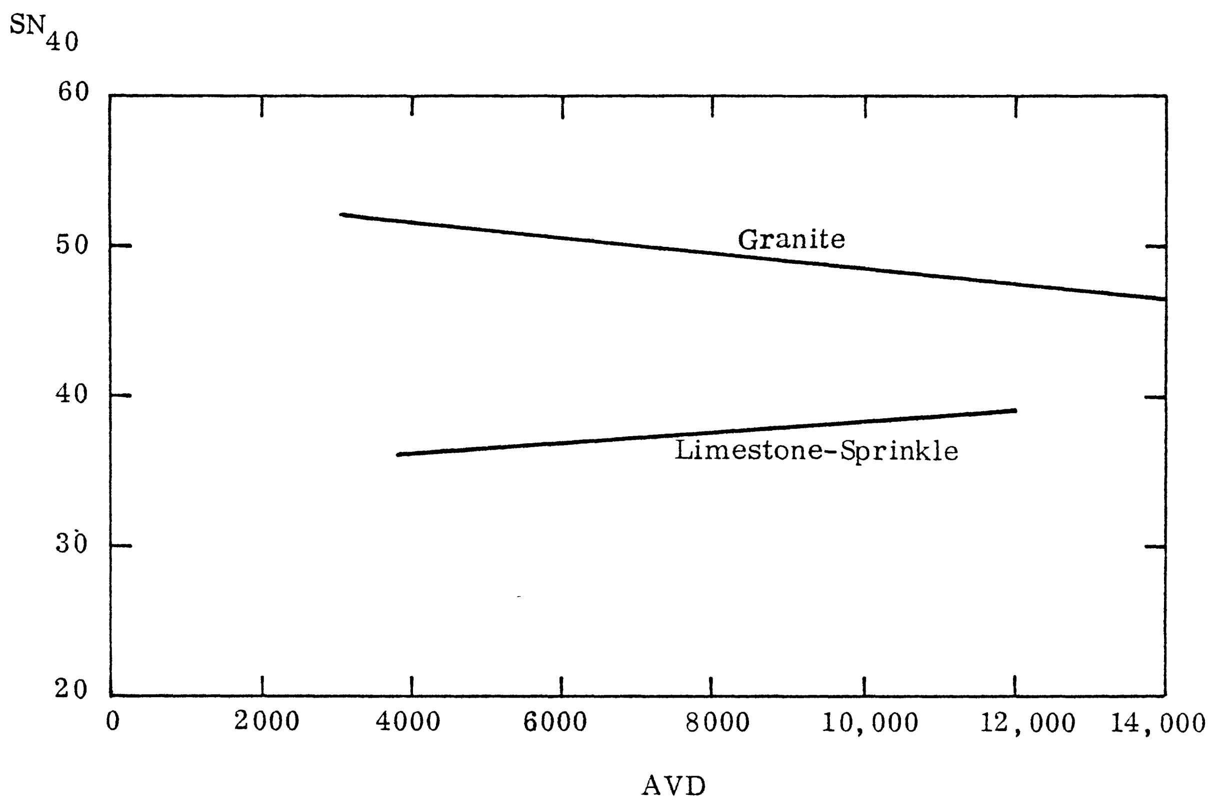

Figure 6. SN_{40} versus AVD.

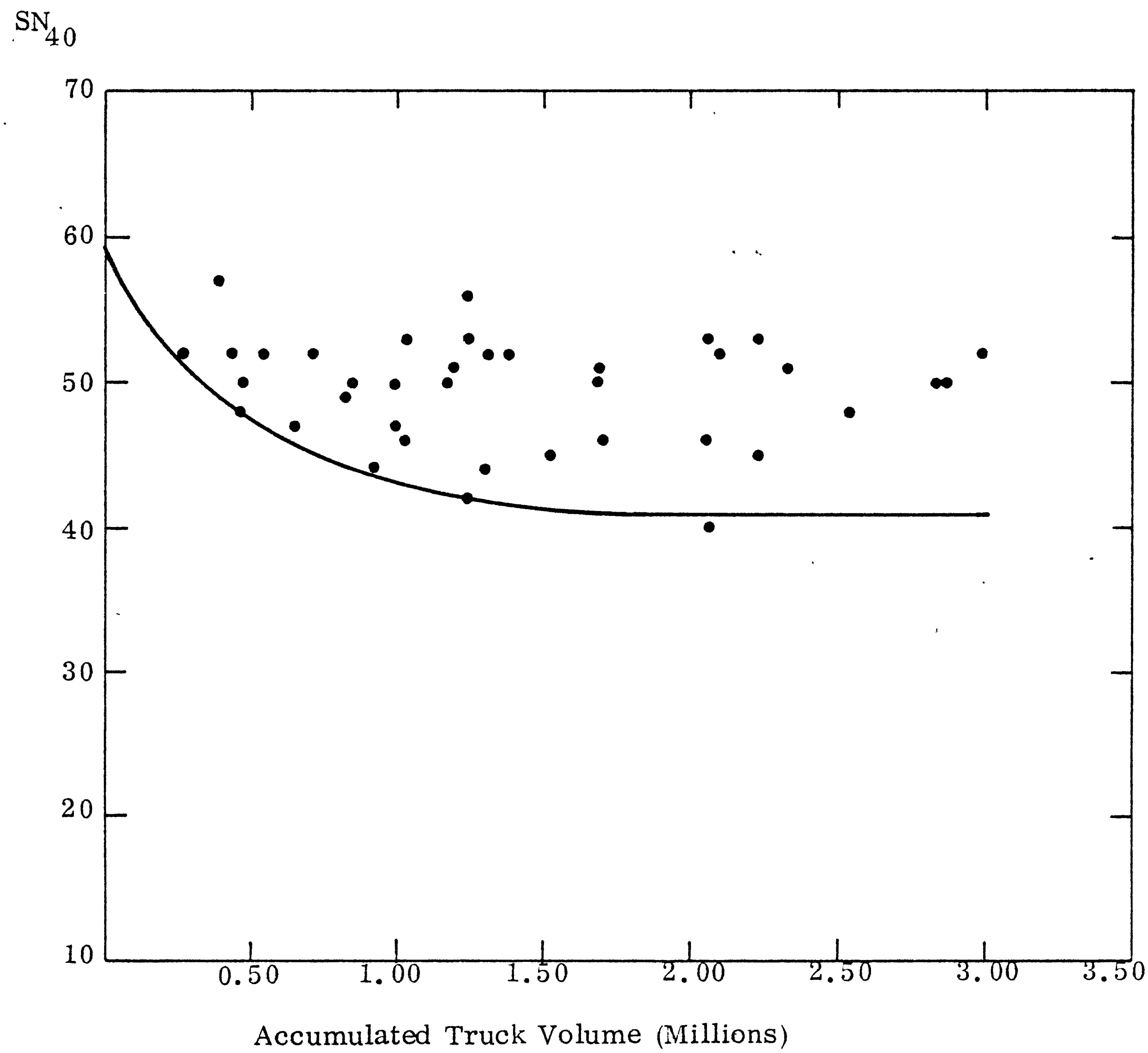

Figure 7. Minimum curve for General Crushed Stone, accumulated truck volume versus SN_{40}.

Table 1

Example of Data Collection by Surface Mix Sections

Source: General Crushed Stone, Doswell

Aggregate: Granite

Mix: S-5

County	Route	Beginning Mile Post Ending Mile Post	Type	Lane	Age In Years	Mo/Yr Tested	SN_{40}	Sample Size (N)	AVD	Accumulated Volume (millions)		Site
										Passenger Cars	Trucks and Buses	
Essex	17	18.15 - 18.48	4-lane	NBTL	2.0	4/76	52	3	6,185	1.845	0.631	1
Middlesex	17	14.23 - 15.07	4-lane	NBTL	8.0	"	44	3	6,165	5.486	1.783	2
				SBTL	8.0	"	48	2	"	"	"	2
Gloucester	17	2.02 - 2.68	2-lane	NBTL	7.5	"	48	1	3,235	2.922	0.978	3
				SBTL	"	"	49	1	"	"	"	3
Gloucester	17	5.30 - 6.12	2-lane	NBTL	"	"	50	3	"	"	"	3
				SBTL	"	"	49	1	"	"	"	3
Gloucester	17	16.02 - 16.94	4-lane	NBTL	10.0	"	48	5	10,395	12.914	2.970	4
Gloucester	17	16.02 - 17.44	4-lane	SBTL	8.0	"	45	5	"	10.879	2.611	5
Gloucester	17	17.79 - 17.98	4-lane	SBTL	"	"	48	2	"	"	"	5
Gloucester	17	20.59 - 20.79	4-lane	SBTL	"	"	42	2	"	"	"	5

Table 2.

Example of Data Summarized by Site

Source: General Crushed Stone, Doswell, Virginia

Aggregate: Granite

Site	Total Accumulated Volume, Millions	Lane Distribution	Lane Volume, Millions	Accumulated Trucks & Buses, Millions	Lane Distribution	Lane Volume, Millions	Truck Lane Volume/Age	AVD	SN_{40}		Date Tested
									$\overline{X}$	N	
1	2.48	83%	2.06	0.63	85%	0.54	0.27	6,185	52	3	4/76
2	7.27	83%	6.03	1.78	85%	1.51	0.19	6,165	45	5	"
3	3.90	100%	3.90	0.98	100%	0.98	0.13	3,235	50	6	"
4	15.88	78%	12.39	2.97	85%	2.52	0.25	10,395	48	5	"
5	13.49	78%	10.52	2.61	85%	2.22	0.28	10,395	45	9	"

Table 3

Factors for Assignment of Lane Volumes

ghway Type	AVD	Total Vehicles			Trucks & Buses		
		% Outside Lane	% Center Lane	% Inside Lane	% Outside Lane	% Center Lane	% Inside Lane
lane	All	100	—	-	100	-	-
lane	0-4,000	88	-	12	85	-	15
	4-8,000	83	-	17	85	-	15
	8-12,000	78	-	22	85	-	15
	12-16,000	76	-	24	85	-	15
	16-20,000	72	-	28	85	-	15
	20-24,000	69	-	31	85	-	15
	24-28,000	66	-	34	85	-	15
	28-32,000	64	-	36	85	-	15
	32-36,000	61	-	39	85	-	15
	36-40,000	60	-	40	85	-	15
	> 40,000	58	-	42	85	-	15
lane	30-60,000	24	51	25	70	25	5

Table 4.

Rating System for Skid Resistance Potential of Aggregates

Lowest SN_{40} Value In 3.0 Million Accumulated Truck Volume	Rating	Comments
≥ 50	Excellent	Should satisfy almost all skid resistance requirements.
40-49	Good	Should satisfy most conditions for 2-lane and high volume divided highways with exceptions because of severe geometric or intersection conditions.
30-39	Marginal	Should satisfy most conditions with good geometrics; however, should not be used as the non-polishing aggregate portion of a blended or sprinkle mix.
< 30	Poor	Not desirable for use except where projected accumulated truck volume would place minimum SN_{40} at a value above 30.

Table 5.

Aggregate Skid Resistance Ratings by Source

PRODUCER	LOCATION	AGGREGATE TYPE	RATING	STATUS	FIG.
ACCO Stone Corp	Blacksburg, Va.	Dolomite			
ACME Limestone Co.	Ft. Spring, W. Va.	Limestone			
ACME Stone Co.	Abingdon, Va.	Limestone			
Adams Stone Co.	Burdine, Ky.	Limestone	Poor	Sprinkle	A-1
American Limestone	Blaintville, Tenn.				
	Watauga, Tenn.				
Appomattox Lime Co.	Appomattox, Va.	Marble			
	Staunton, Va.				
Ararat Rock Products	Mt. Airy, N. C.	Gneiss			
Arvonia Buckingham Slate Co.	Arvonia, Va.	Slate			
Agusta Stone Co.	Staunton, Va.	Limestone/Dolomite			
Barger, C. W. & Sons	Lexington, Va.	Limestone			
Bear & R. Quarry, Inc.	Atkins, Va.	Otzite/Gneiss			
Belmont Quarry	Staunton, Va.	Limestone/Dolomite			
Bishop, W. R.	Hamsan	Gravel			
Blue Ridge Stone Co.	Blue Ridge, Va.	Limestone/Dolomite			
	Lynchburg, Va.	Marble	Marginal	-	A-2
Bosobel Granite	Manakin, Va.	Granite/Gneiss			
Bull Run Stone Co.	Manassas, Va.	Diabase			
	Burkeville, Va.				
Burkeville Stone	Burkeville, Va.	Gneiss	Good	-	A-3
Cardinal Stone	Galax, Va.				
	Independence, Va.	Gneiss			
Caroline S. & G	Fredericksburg, Va.				
Chantilly Crushed Stone	Chantilly, Va.	Diabase	Good	Tentative	A-4
Charlottesville Stone Co.	Shadwell, Va.	Greenstone	Good	Tentative	A-5
Chemstone Corp.	Strasburg, Va.	Limestone/Dolomite			
Clinch River Quarry	St. Paul, Va.	Limestone	Poor	Sprinkle	A-1
Contracting Services, Inc.	Whitesburg, Ky.	Limestone/Dolomite			
Crowder, H. D. & Sons	Poplar Camp, Va.	Limestone			
	Carroll Co., Va.	Gneiss			
Culpeper Stone Co.	Stevensburg, Va.	Shale/Mudstone	Marginal	Tentative	A-6
Delp Quarry	Comers Rock, Va.	Quartz			
Dominion Materials	Piney River, Va.	Aplite	Good	Tentative	A-7
Elkorn Stone	Elkorn, Ky.	Limestone			
Elkton Limestone Co.	Elkton, Va.	Limestone/Dolomite			

Table 5 continued

PRODUCERS	LOCATION	AGGREGATE TYPE	RATING	STATUS	FIG.
Fairfax Quarry	Manassas, Va.	Diabase	Good	Tentative	A-8
	Manassas, Va.	(PCC)	Good	Tentative	A-9
Flat Rock Quarry	Forestville, Va.	Limestone/Dolomite			
Flint Hill Stone	Flint Hill, Va.	Granodiorite	Good	-	A-10
Fox Sand and Gravel	Aylett, Va.	Gravel			
Fraziers Quarry	Harrisonburg, Va.	Limestone			
Fredericksburg S & G	Fredericksburg, Va.	Gravel			
	Fredericksburg, Va.	(PCC)	Good?	-	A-11
Frey, W. S. & Co.	Clearbrook, Va.	Limestone			
Friend & Co.	Petersburg, Va.	Gneiss			
		(PCC)	Marginal	-	A-12
General Crushed Stone	Verdon, Va.	Granite	Good	-	A-13
Grayson Stone Co.	Galax, Va.	Quartzite/Gneiss			
Grottoes Sand & Gravel	Grottoes, Va.	Gravel	Excellent	Tentative	A-14
Grove, M. J. Lime	Frederick, Md.	Limestone			
	Middletown, Va.	Limestone/Dolomite			
	Stephens City, Va.	Limestone/Dolomite			
Holston River Quarries	Marion, Va.	Limestone	Poor	Sprinkle	A-1
	Nicks Creek, Va.	Quartzite			
Interstate Stone Co.	Front Royal, Va.	Limestone/Dolomite			
James River Hydrate	Swords Creek, Va.	Dolomite			
Jamison Black Marble	Harrisonburg, Va.	Limestone			
Jones & Laughin Steel Co.	Millville, Va.	Limestone/Dolomite			
Kendall Sand Works	Danville, Va.	Granite	Good	Tentative	A-15
Kentucky-Va. Stone Co.	Gibson Station, Va.	Limestone			
Leesburg Stone Co.	Leesburg, Va.	Diabase			
LeSueur Richmond Slate	Buckingham, Va.	Slate			
Liberty Limestone	Buchanan, Va.	Limestone/Dolomite			
Lonejack Limestone	Glasgow, Va.	Dolomite			
	Glasgow, Va.	Quartzite	Good	Tentative	A-16
Lonestar Industries:					
Dale Quarry	Chester, Va.	Granite/Gneiss	Good	Tentative	A-17
Dock St.	Richmond, Va.	Gravel	Good	Tentative	A-18
Jack Quarry	Petersburg, Va.	Granite/Gneiss	Good	-	A-19
Jones Neck	Kingsland Reach	Gravel			
Puddledock	Petersburg, Va.	Gravel			
Shirley Rt. 5	Richmond, Va.	Gravel			
Willis Road	Kingsland Reach	Gravel			
Loudon Quarry - 1	Herndon, Va.	Diabase			

Table 5 continued

PRODUCERS	LOCATION	AGGREGATE TYPE	RATING	STATUS	FIG.
Martinsville Stone Co.	Fieldale, Va.	Gneiss	Good	Tentative	A-20
Marty Corp.	Eaststone Gap, Va.	Limestone	Poor	Sprinkle	A-1
Massaponax S & G	Fredericksburg, Va.	Gravel	Good	Tentative	A-21
Mattaponi S & G	Duane, Va.	Gravel			
	Duane, Va.	(PCC)	Good	Tentative	A-22
Mercer Crushed Stone	Mercer Co., W. Va.	Limestone			
Montgomery Limestone	Ellett, Va.	Limestone			
	Showsville, Va.	Limestone			
Munday, C. S.	Singer's Glen, Va.	Limestone/Dolomite			
Natural Tunnel Stone	Glenita, Va.	Limestone/Dolomite			
New Jersey Zinc Co.	Ivanhoe, Va.	Limestone			
Newman Bros.	Sylratus, Va.	Quartzite	Good	-	A-23
Parker Sand & Gravel	Providence Forge, Va.	Gravel			
Pendleton Const. Co.	Cripple Creek, Va.	Quartz			
	Rocky Gap, Va.	Limestone/Dolomite			
	Wytheville, Va.	Dolomite			
Perry, Stuart M.	Berryville, Va.	Dolomite			
	Winchester, Va.	Limestone/Dolomite			
Pope, R. G. Quarry	Dickensonville, Va.	Limestone			
Pounding Mill Quarry #1	Pounding Mill, Va.	Limestone	Poor	Sprinkle	A-1
	Bluefield, Va. #2	Limestone	Poor	Sprinkle	A-1
Port Royal S & G	Woodford, Va.	Gravel	Good	Tentative	A-24
Pruitt Soil & Aggregate Co.	Milford, Va.	Gravel			
Quality Sand & Gravel	Guinea, Va.	Gravel			
Radford Stone Corp.	Newborn, Va.	Limestone			
	Radford, Va.	Limestone			
Richmond Crushed Stone	Oilville, Va.	Granite	Marginal	Tentative	A-25
Riverton Lime & Stone Co.	Leaksville, Va.	Limestone			
	Riverton, Va. #1	Limestone			
	Riverton, Va. #2	Limestone			
	Riverton, Va.	Greenville	Good	Tentative	A-26
Rockville Stone Co.	Hylas, Va.	Granite/Gneiss	Good	Tentative	A-27
Rockydale Quarries	Lynchburg, Va.	Marble	Marginal	-	A-28
Royal Stone Co.	Hylas, Va.	Granite/Gneiss			
Sadler Sand & Gravel	Richmond, Va.	Gravel			
Salem Stone	Dixie Caverns, Va.	Limestone	Poor	Sprinkle	A-1
	Pearisburg, Va.	Limestone			
	Williamsville, Va.	Limestone			
	Elliston, Va.	Gravel	Good	Tentative	A-29
Saunders Quarry	Warrenton, Va.	Quartzite	Good	Tentative	A-30

Table 5 continued

PRODUCER	LOCATION	AGGREGATE TYPE	RATING	STATUS	FIG.
Shenandoah S & G	Island Ford, Va.				
	Luray, Va.	Gravel			
	Shenandoah	Gravel	Good	-	A-31
Smith, A. H.	Louisa, Va.	Granite			
Solite Corp.	Richmond	(PCC)	Good	Tentative	A-32
Southeastern Stone Co.	Gibson Station, Va.	Limestone			
Southwest Quarries	Big Stone Gap, Va.	Limestone			
Southwest Materials	Vesurius, Va.	Gravel	Excellent	-	A-33
Superior Stone Co.	Gordonsville, Va.	Marble			
	Red Hill, Va.	Gneiss	Good	Tentative	A-34
	Rivanna River	Gneiss	Excellent	Tentative	A-35
Tidewater Crushed Stone	Richmond, Va.	Granite	Good	Tentative	A-36
Tidewater Materials Co.	Richmond, Va.	Granite			
Trego Stone Co.	Skippers, Va.	Granite	Marginal	-	A-37
Tri-City Sand Co.	Johnson City, Tenn.	Quartz	Good	Tentative	A-38
Tri-State Lime Co.	Blountville, Tenn.	Limestone			
Valley Stone	Staunton, Va.	Limestone/Dolomite			
Virginia Traprock	Leesburg, Va.	Diabase	Good	Tentative	A-39
Virginia Limestone	Klotz, Va.	Limestone			
Vulcan Materials	Bristol, Va.	Limestone			
	Chatham, Va.	Arkose	Excellent	Tentative	A-40
	Danville, Va.	Gneiss	Good	Tentative	A-41
	Erwin, Tenn.	Quartz	Good	Tentative	A-42
	Kingsport, Tenn.	Limestone			
	Lawrenceville, Va.	Gneiss	Good	Tentative	A-43
	Lexington, Va.	Limestone/Dolomite			
	Lowmoor, Va.	Limestone	Poor	Sprinkle	A-1
	Manassas, Va.	Diabase	Good	Tentative	A-44
	Occoquan, Va.	Granite/Gneiss	Good	-	A-45
	South Boston, Va.	Gneiss	Good	Tentative	A-46
	Waynesboro, Va.	Limestone			
Washington Co. Stone	Glade Spring, Va.	Limestone			
	Saltville, Va.	Limestone/Dolomite			
West Bros. Sand & Gravel	Dolphin, Va.	Gravel			
	Richmond, Va.	Gravel	Good	Tentative	A-47
	Richmond, Va.	(PCC)	Good	Tentative	A-48
White Excavating Co.	Castlewood, Va.	Limestone			
Wilson Quarries	Horse Pasture, Va.	Quartzite			
Woodway Stone Co.	Woodway, Va.	Limestone			

APPENDIX

Minimum curves for aggregate sources.

3896

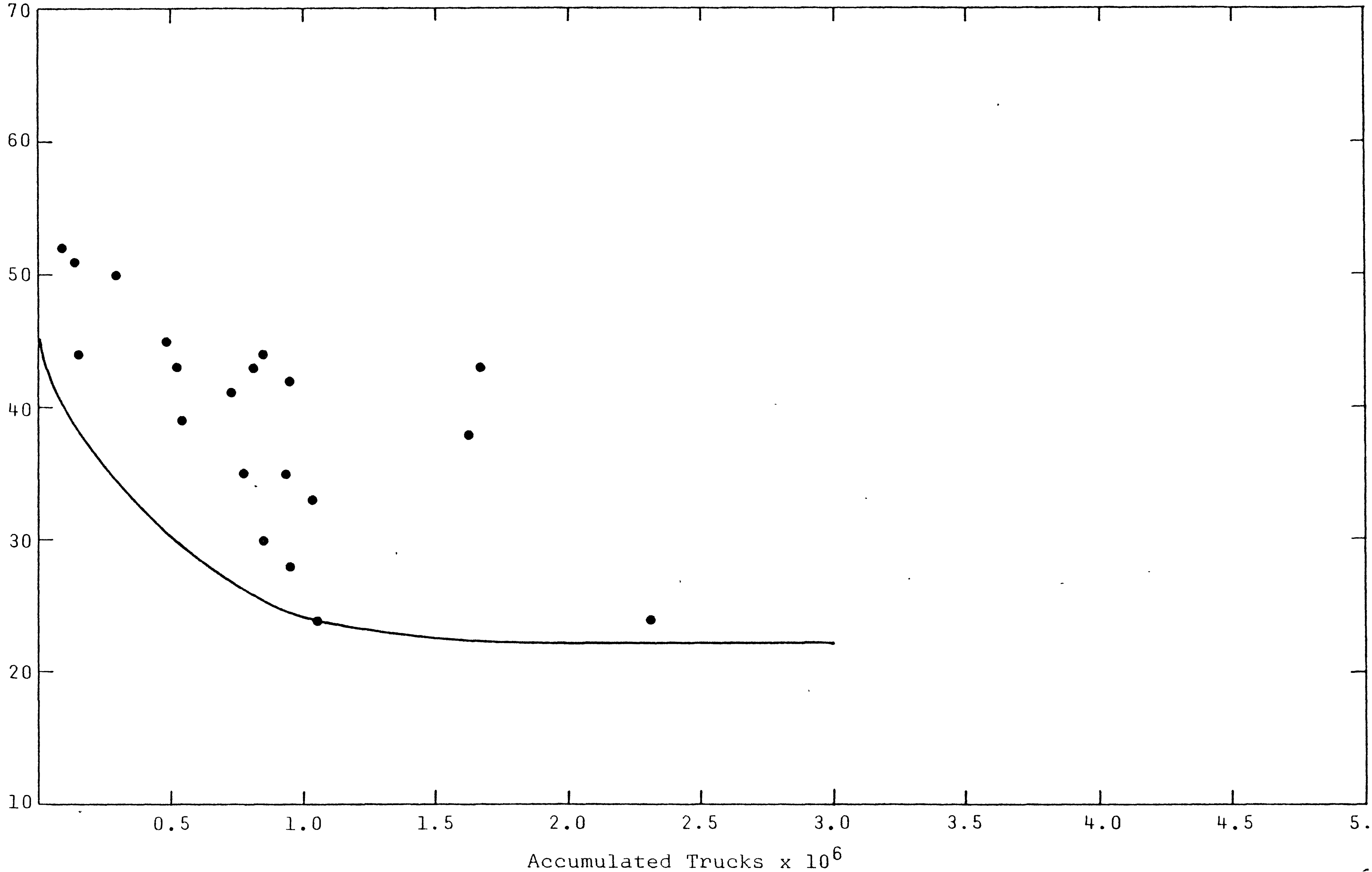

Figure A-1. Limestone Sprinkle Mixes

3897

3898

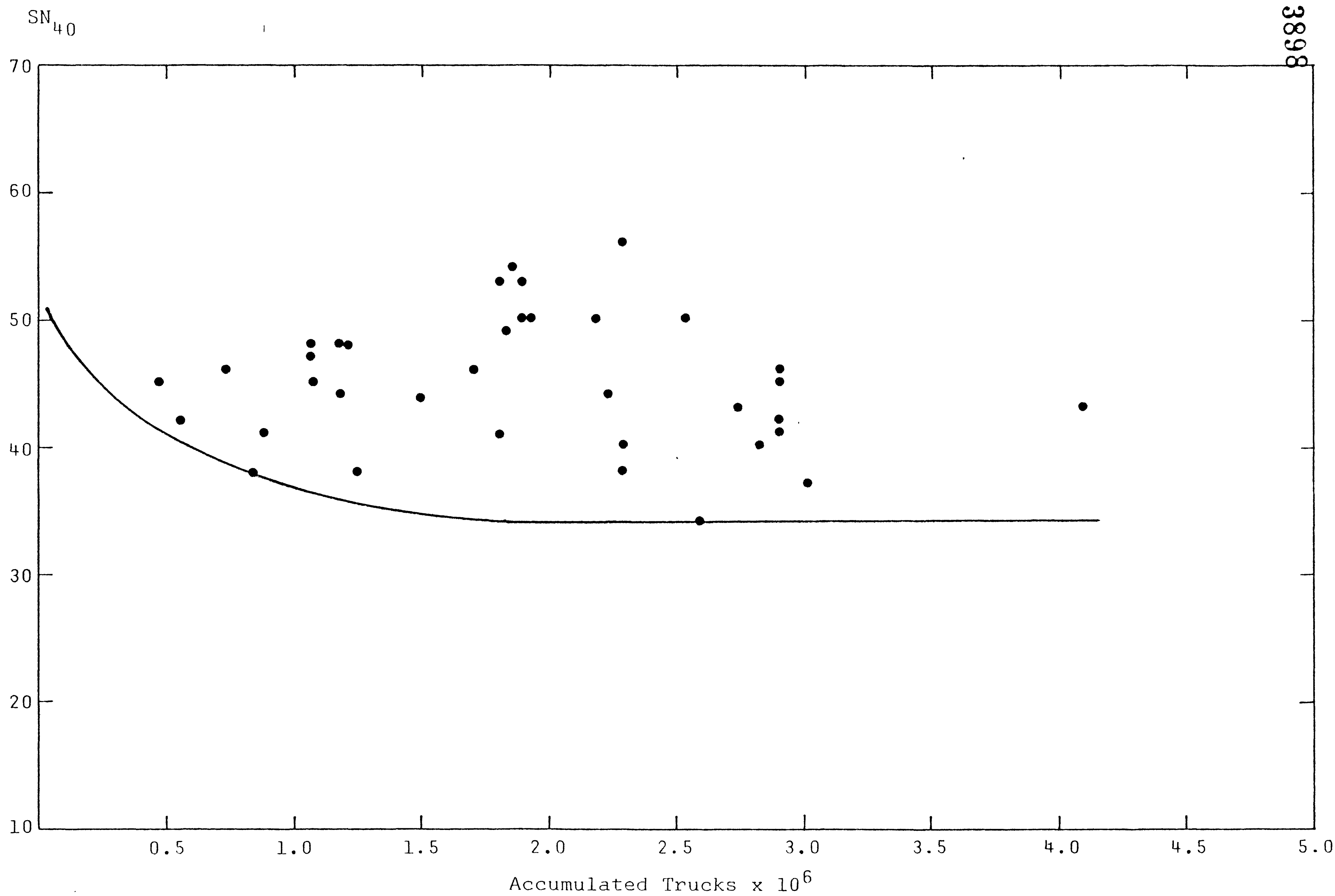

Figure A-2 Blue Ridge Stone—Lynchburg

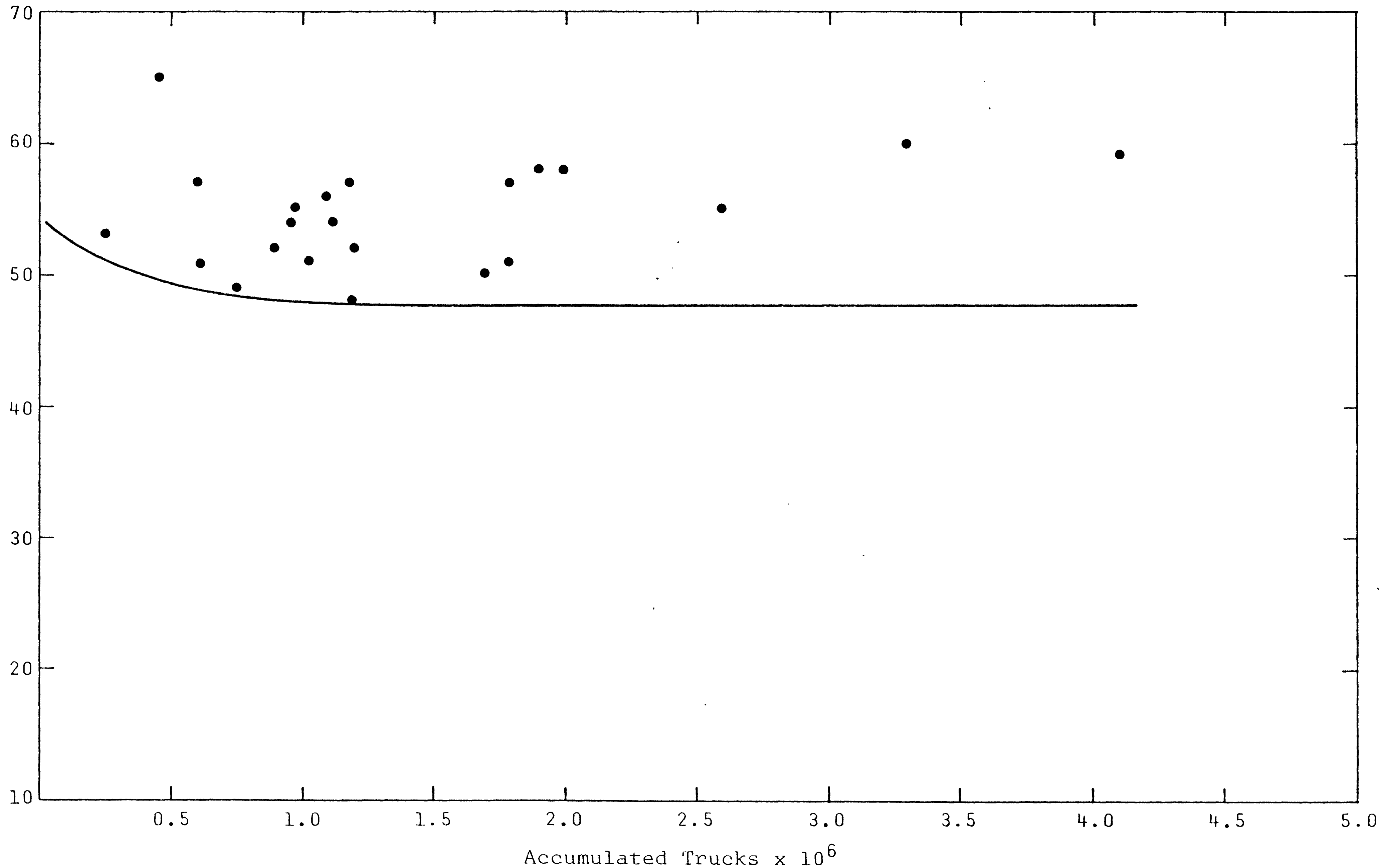

Figure A-3. Burkeville Stone Corp—Burkeville

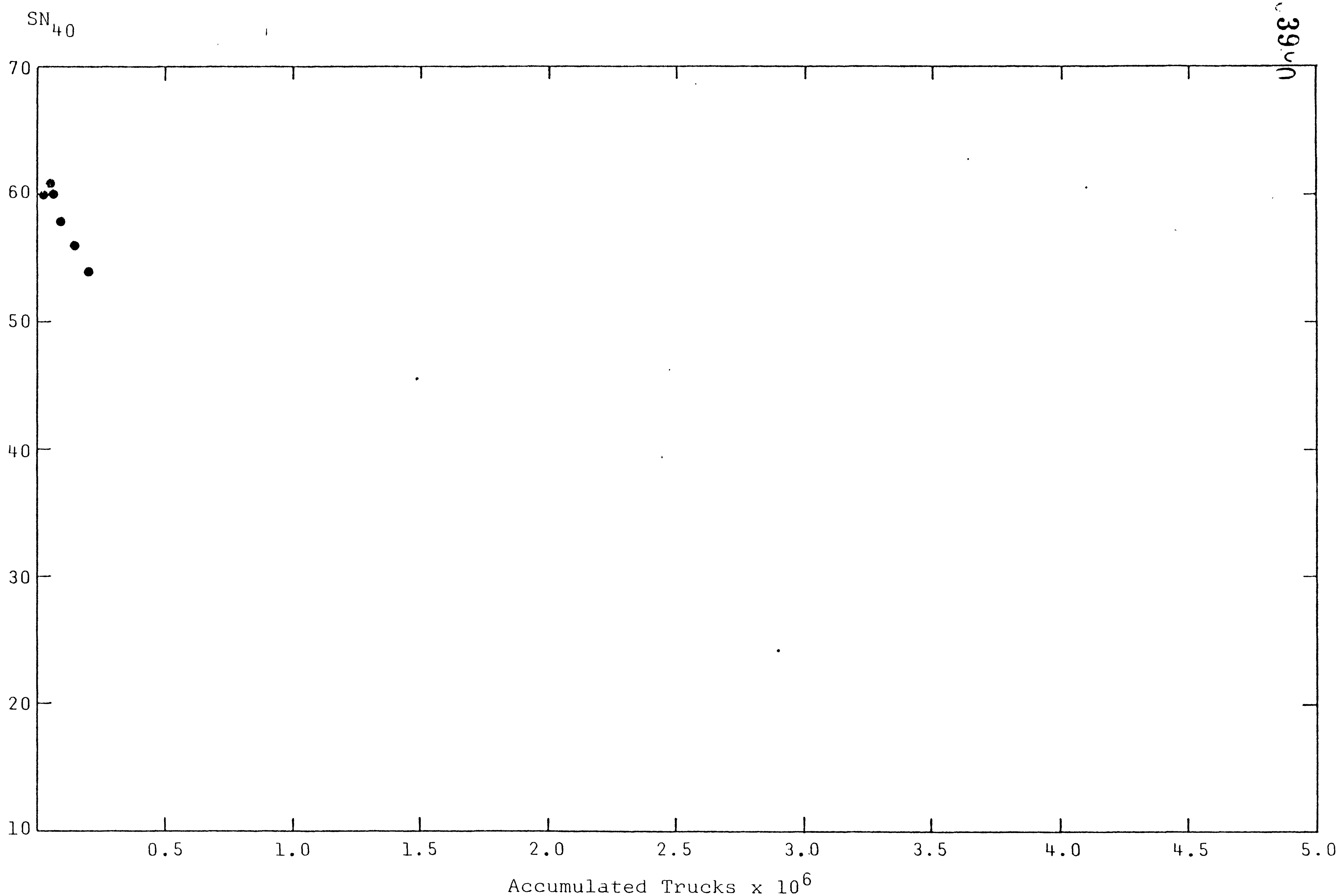

Figure A-4. Chantilly Crushed Stone—Chantilly

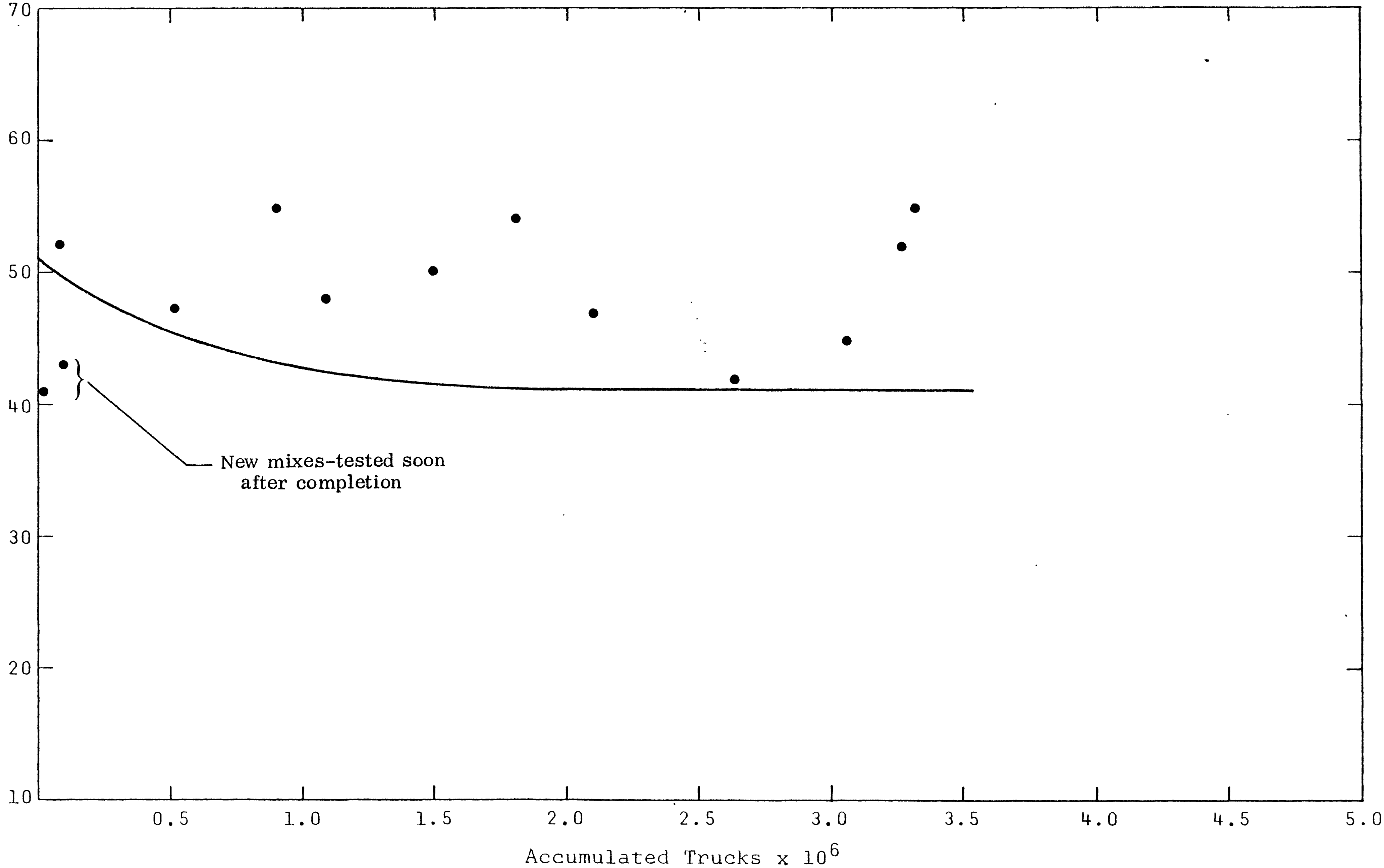

Figure A-5. Charlottesville Stone

3901

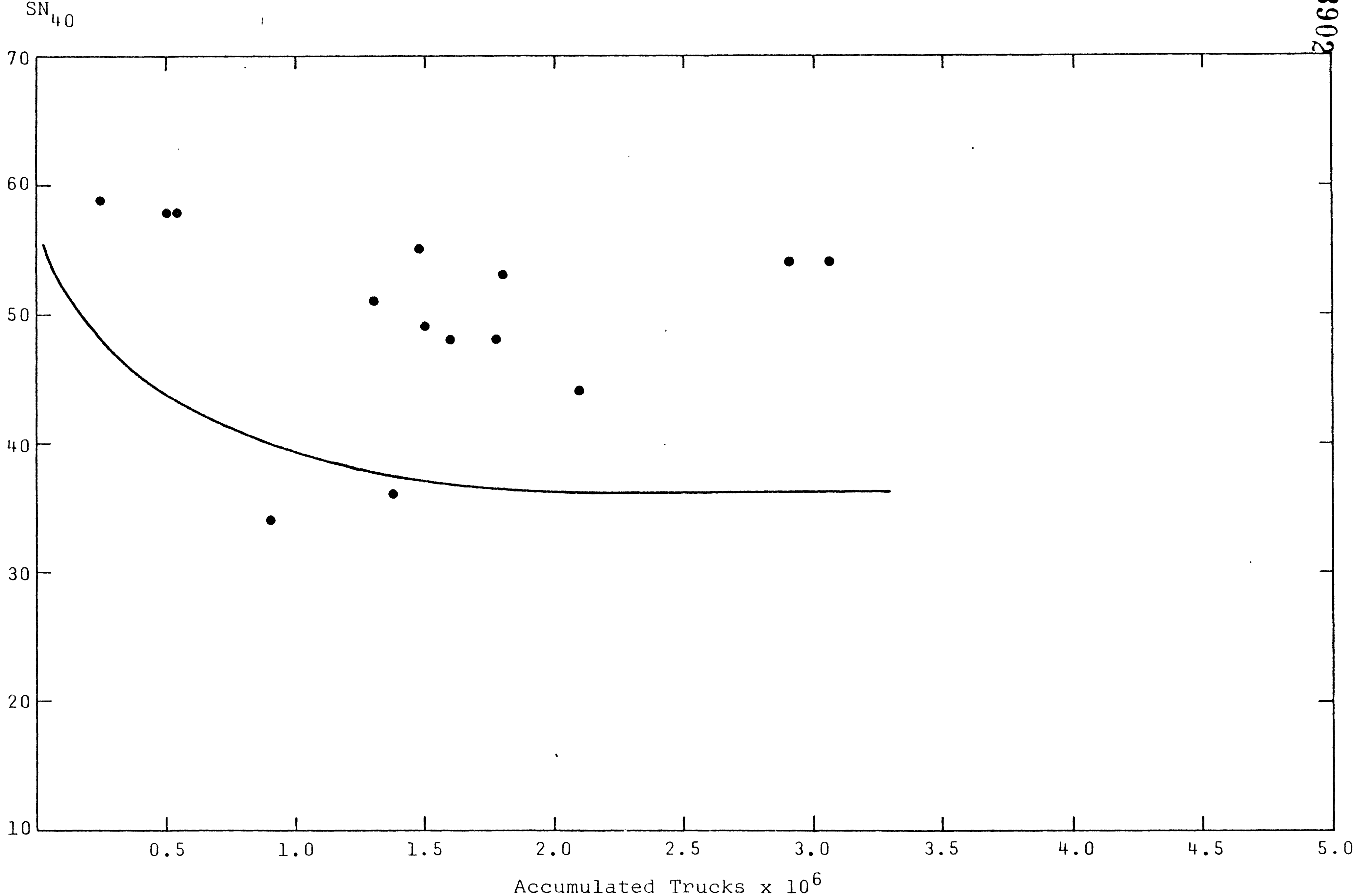

Figure A-6. Culpeper Stone—Culpeper

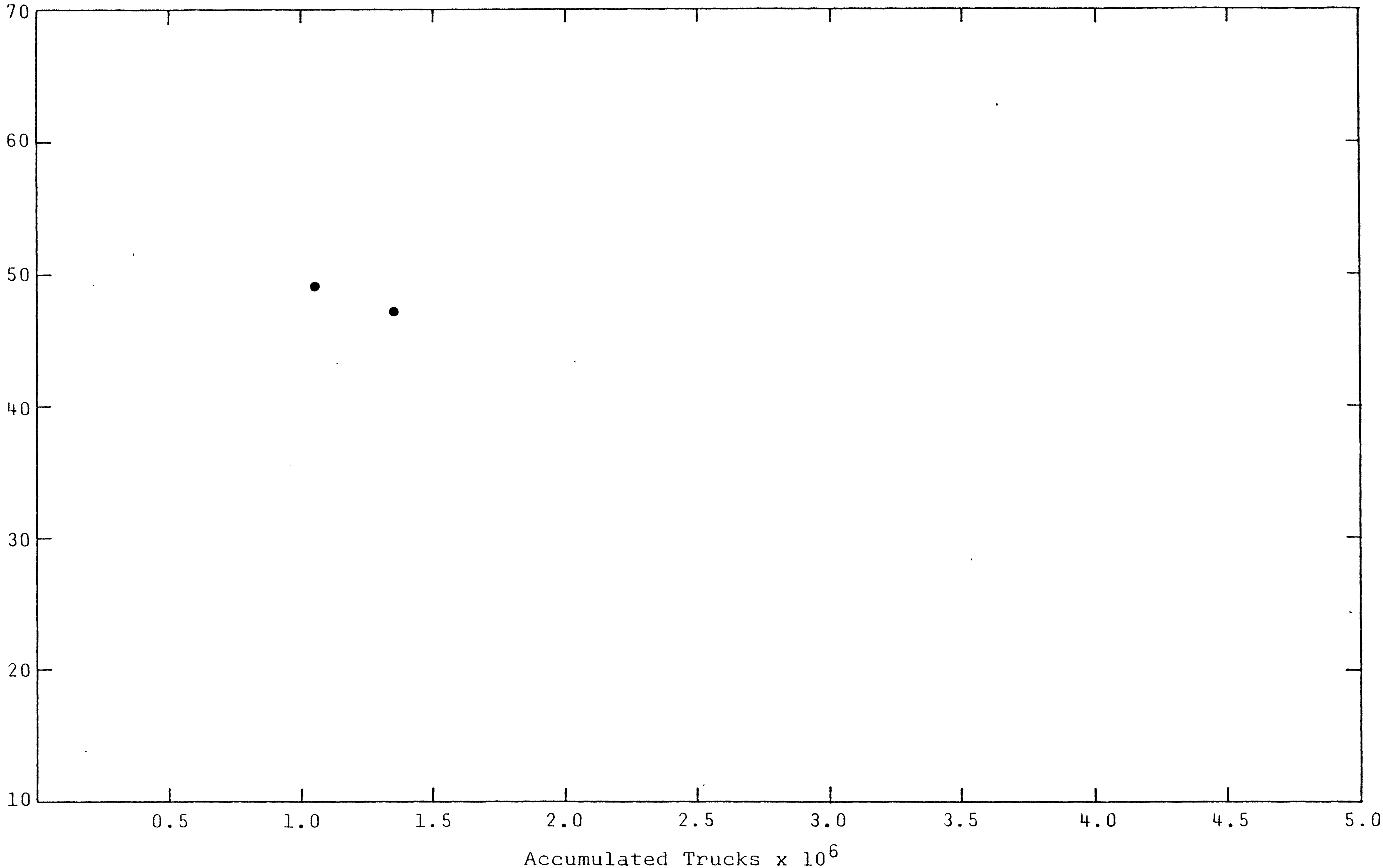

Figure A-7. Dominion Stone—Piney River

00.3903

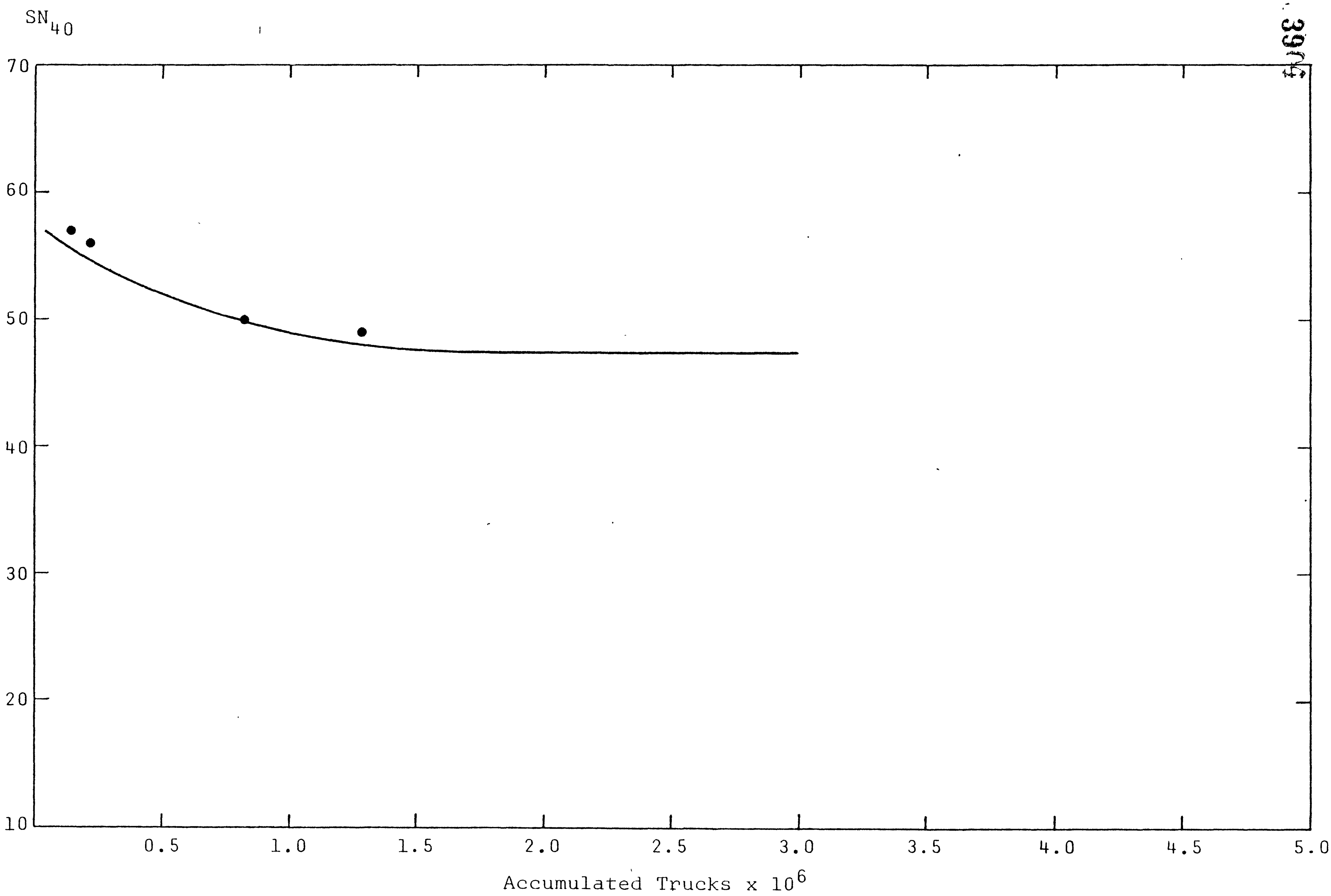

Figure A-8. Fairfax Quarries—Manassas

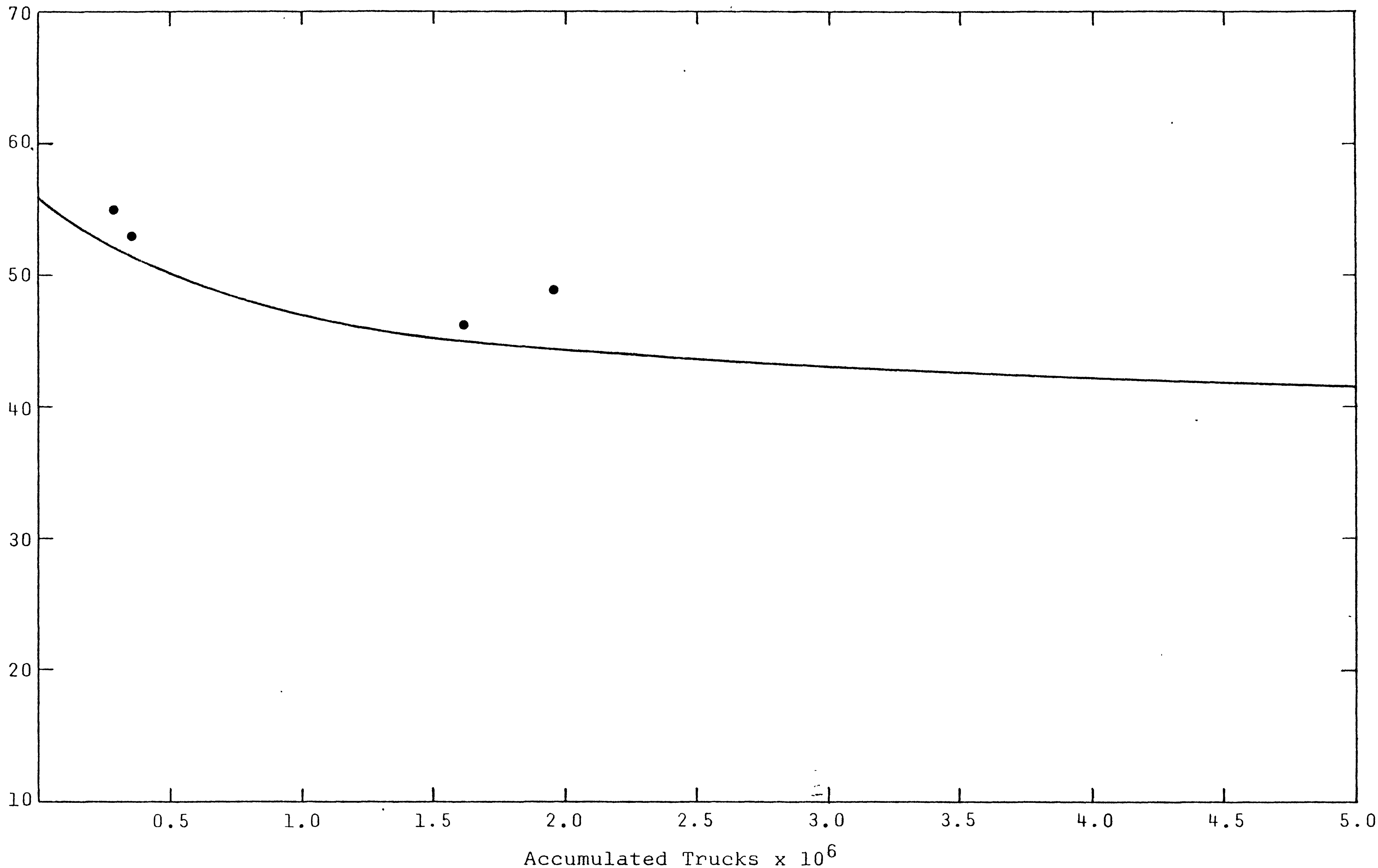

Figure A-9. Fairfax Quarries—Manassas (PCC)

3906

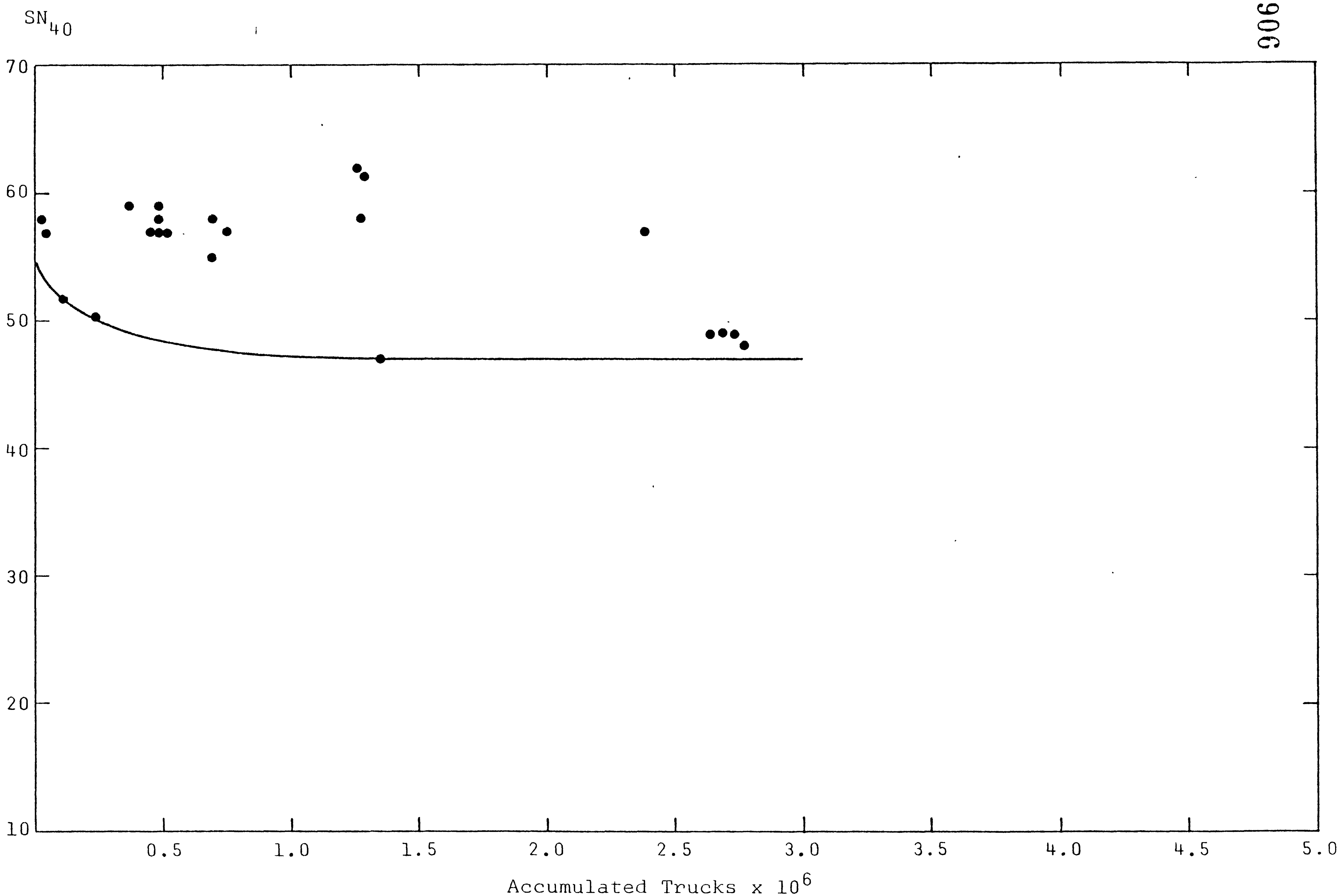

Figure A-10. Flint Hill Stone—Flint Hill

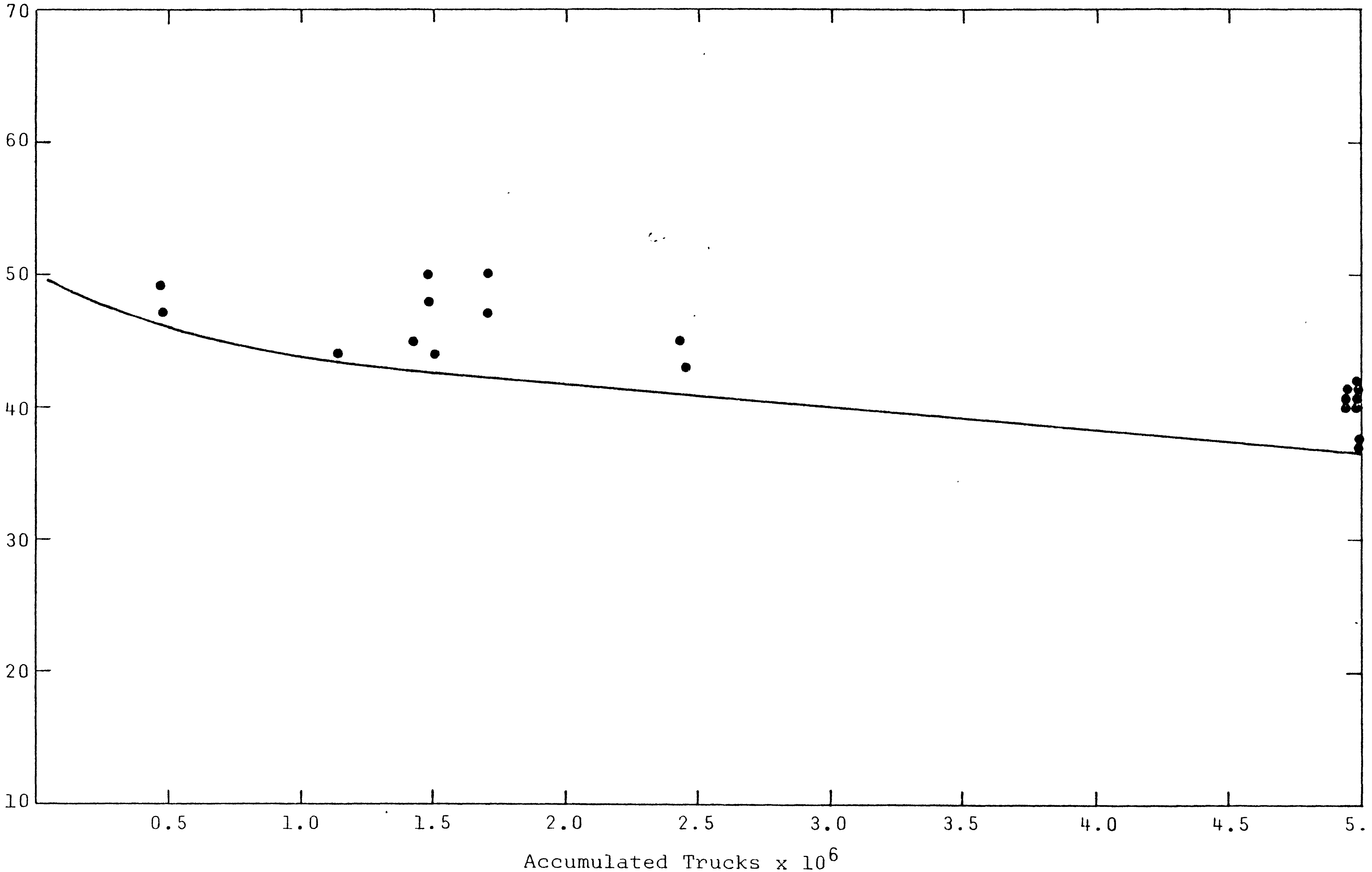

Figure A-11. Fredericksburg Sand and Gravel—Fredericksburg (PCC)

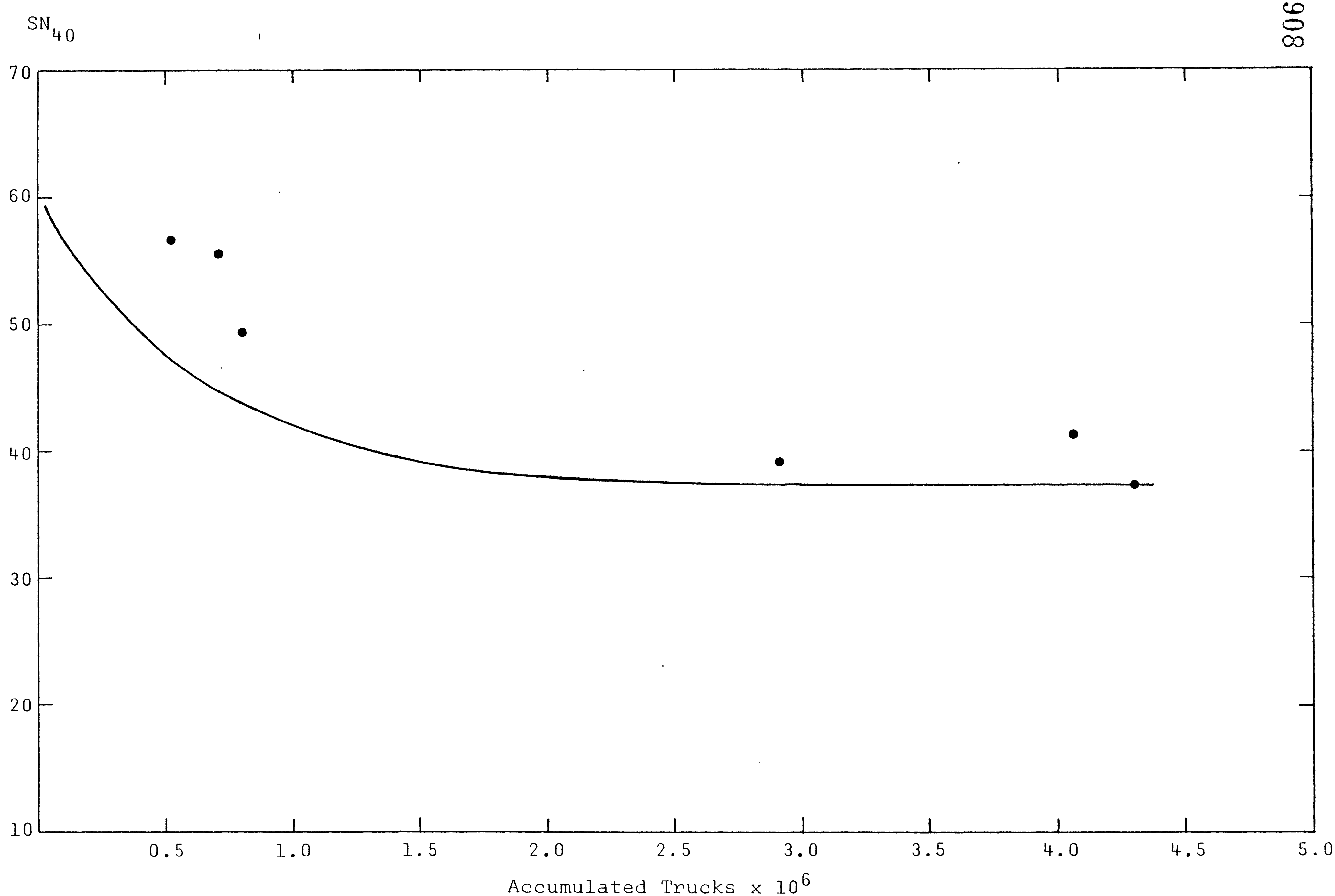

Figure A-12. Friend and Co.—Petersburg (PCC)

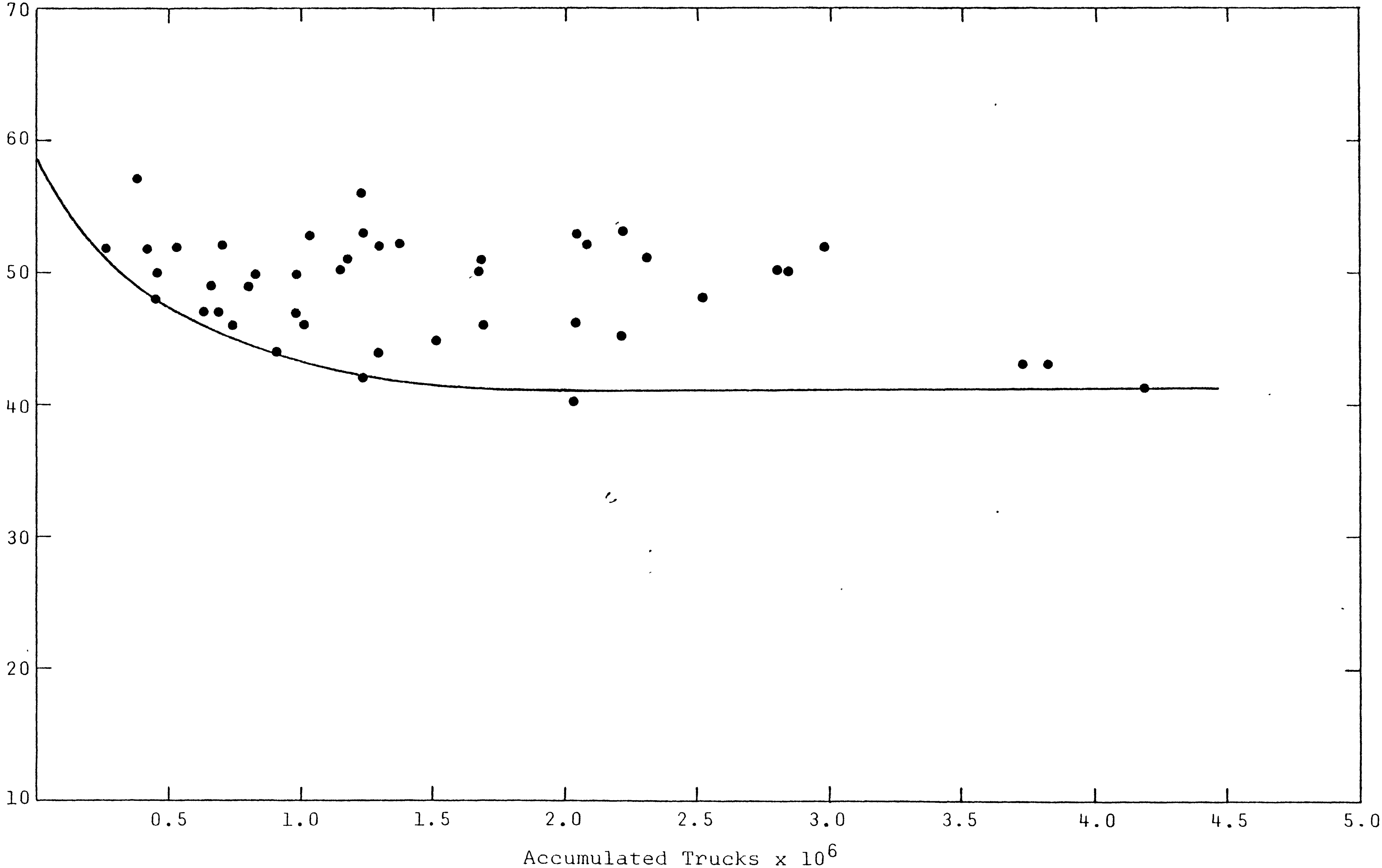

Figure A-13. General Crushed Stone—Doswell

3909

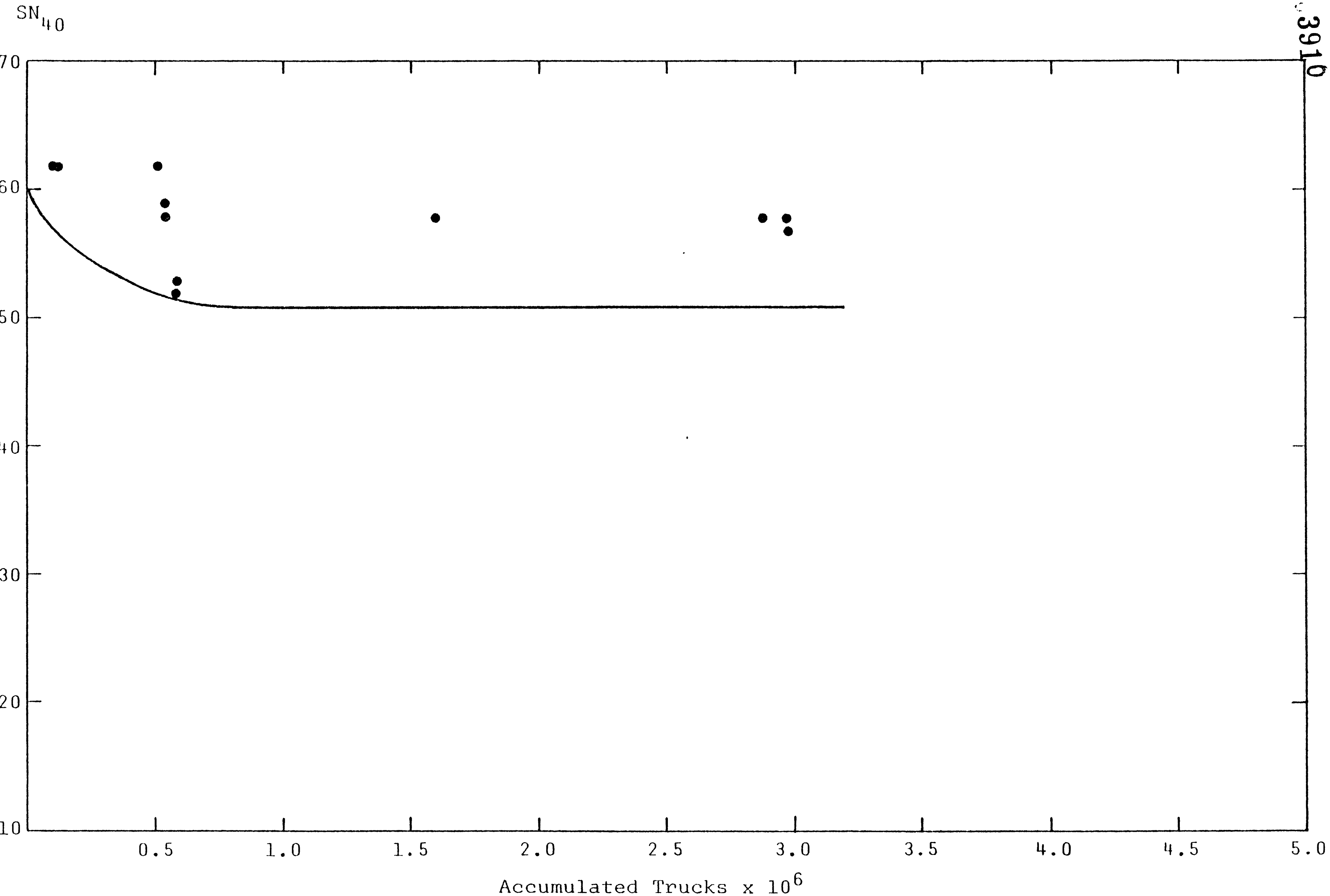

Figure A-14. Grottoes Sand and Gravel

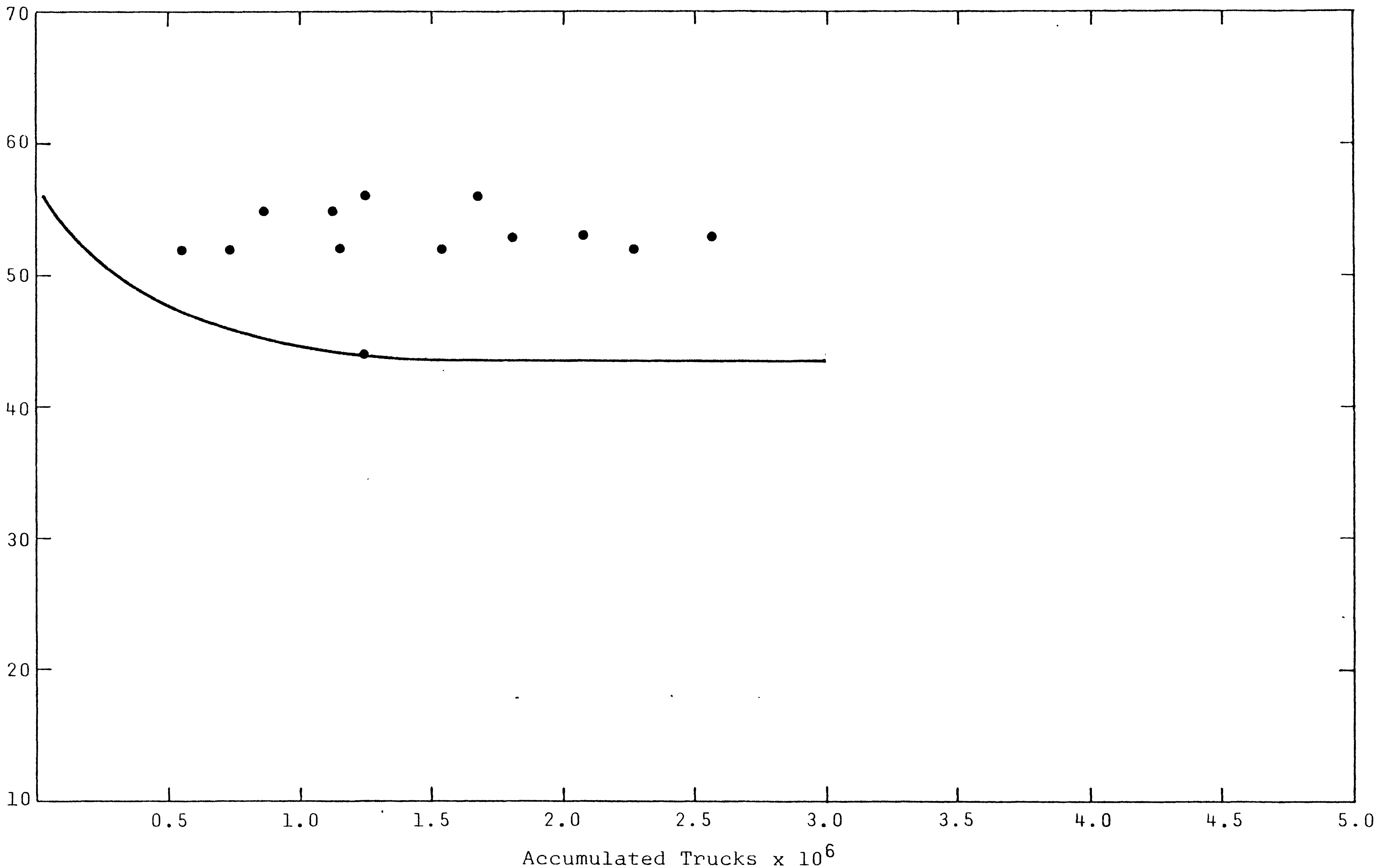

Figure A-15. Kendall Sand Works—Danville

3911

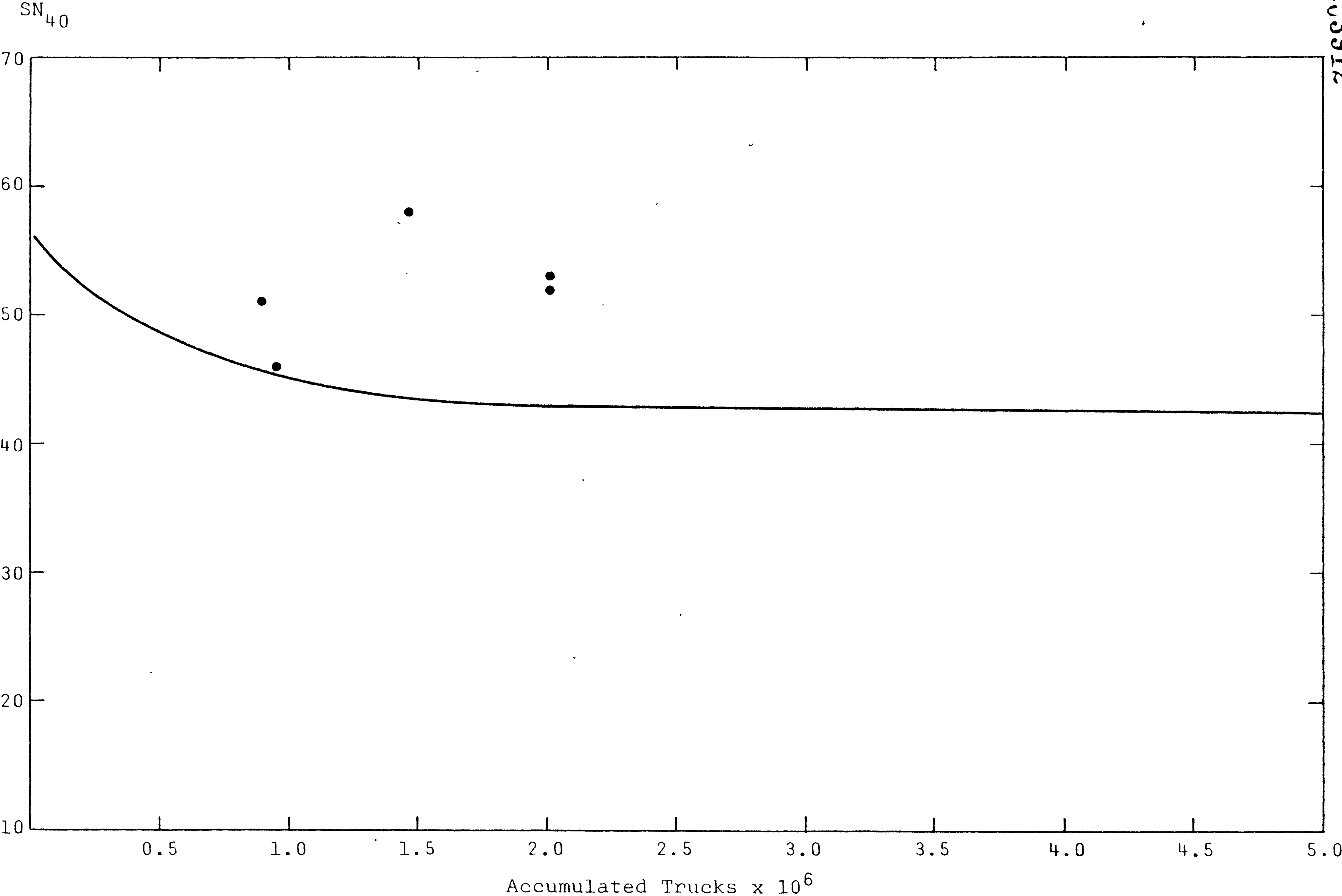

Figure A-16. Lone Jack Limestone—Glasgow, Va.

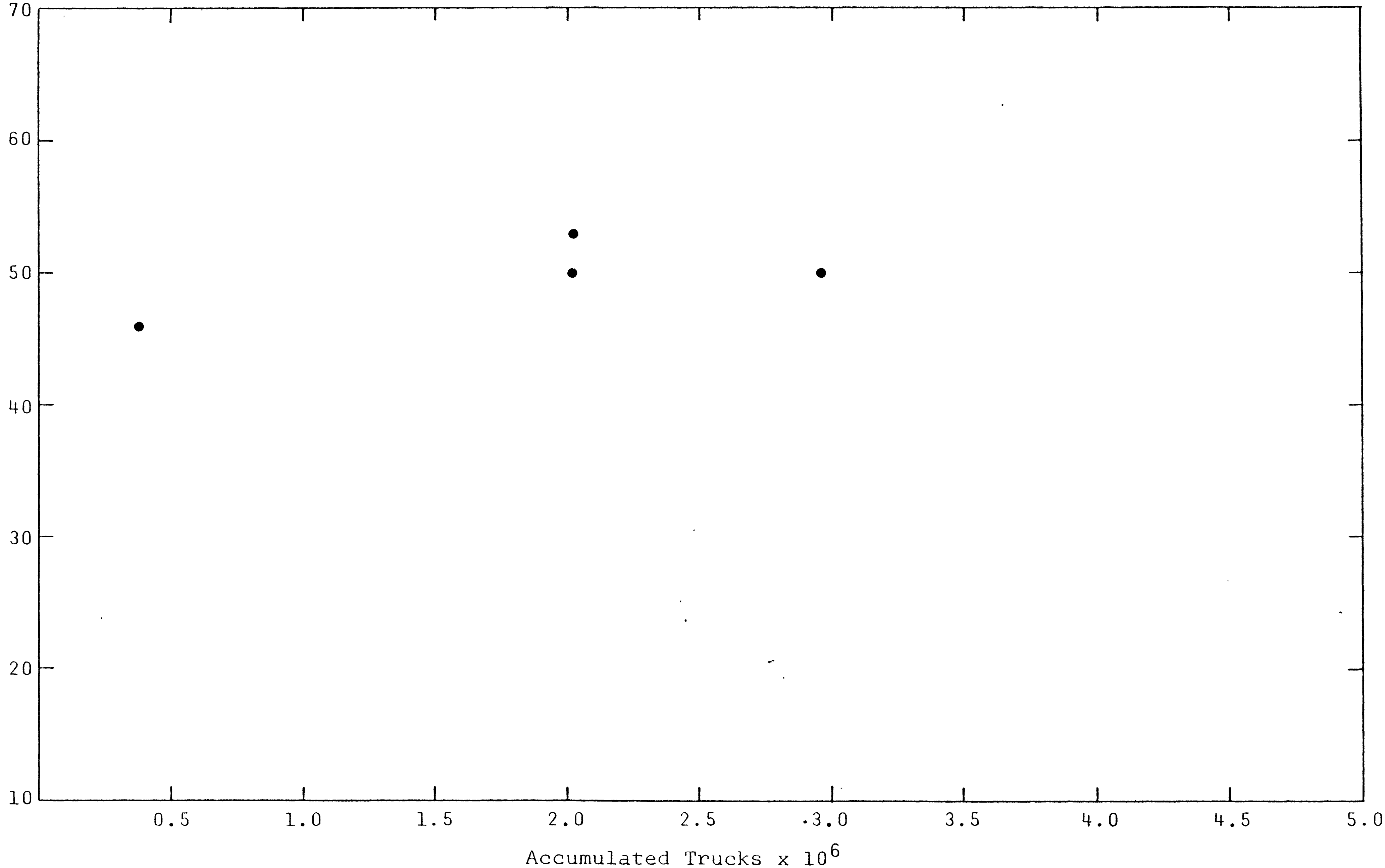

Figure A-17. Lone Star—Chester

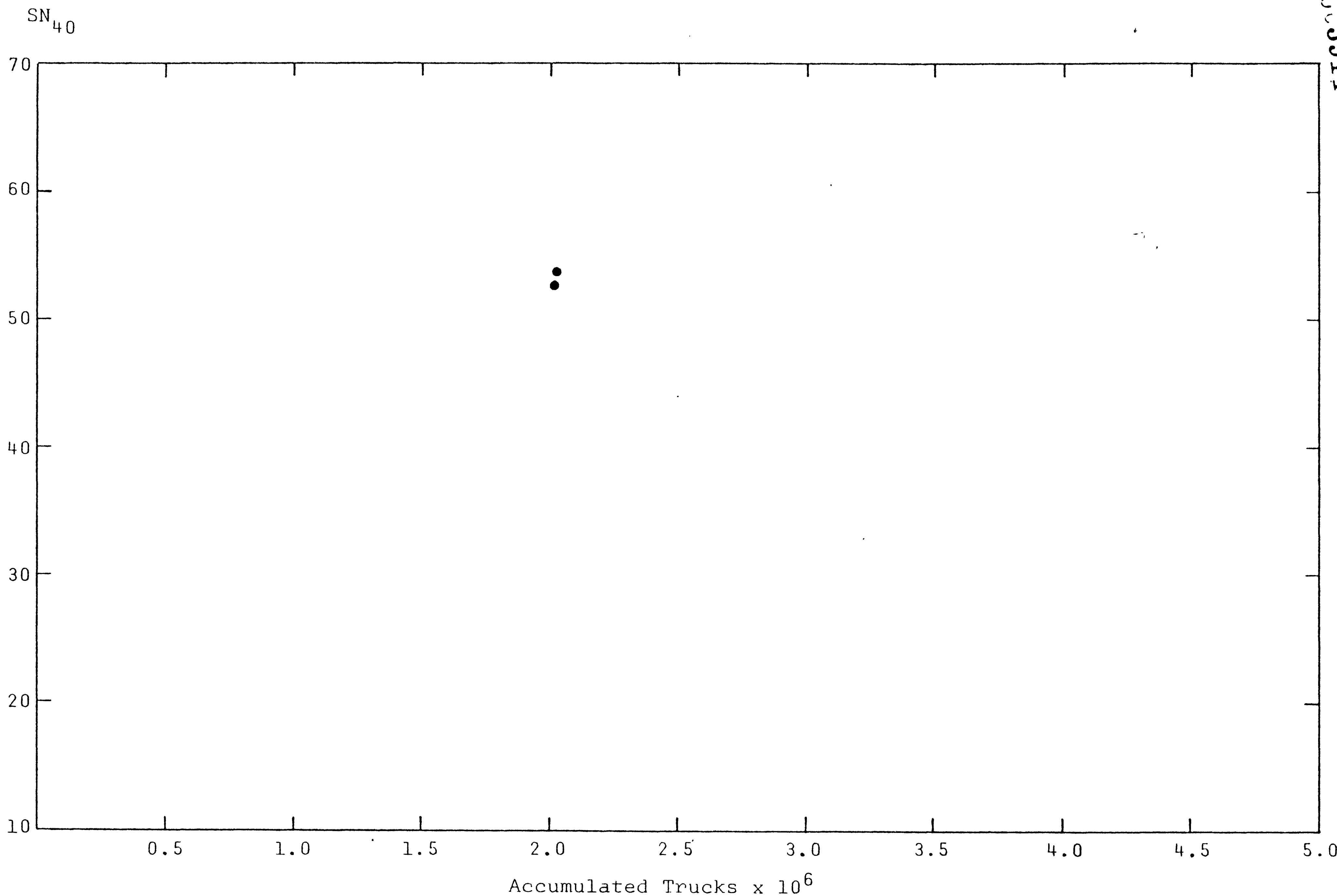

Figure A-18. Lone Star Industries—Richmond (Dock Street)

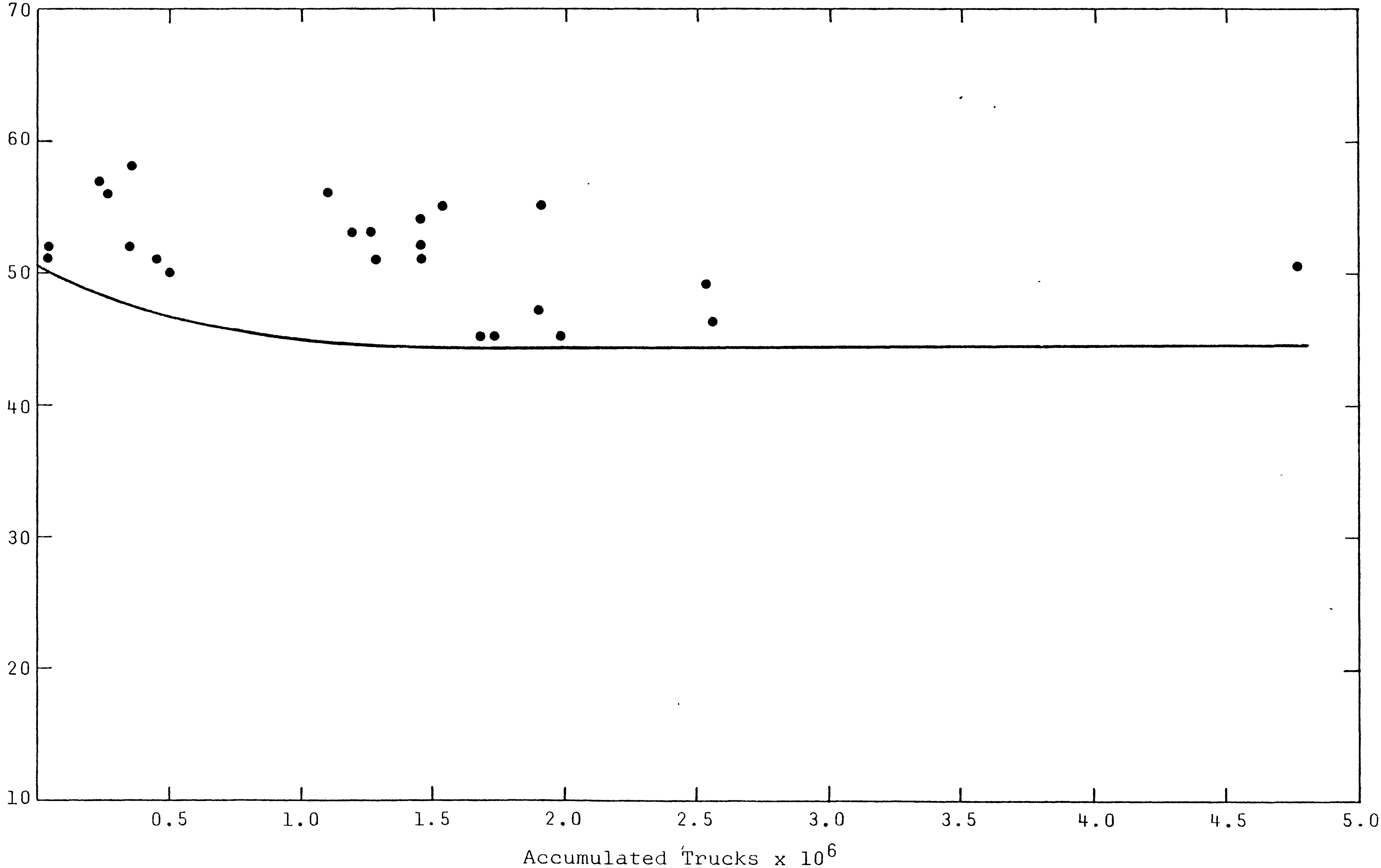

Figure A-19. Lone Star—Petersburg (Jack)

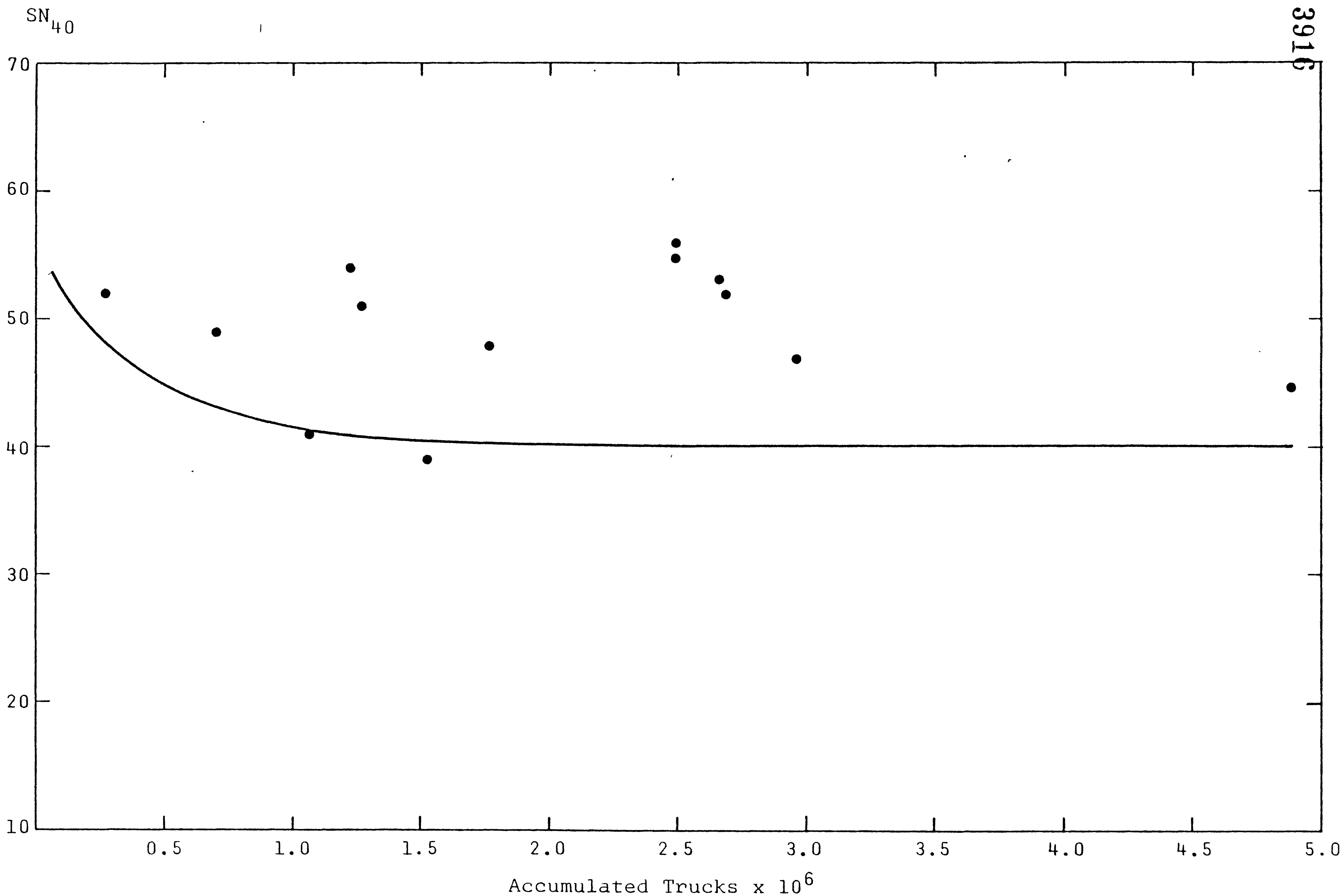

Figure A-20. Martinsville Stone-Martinsville Granite

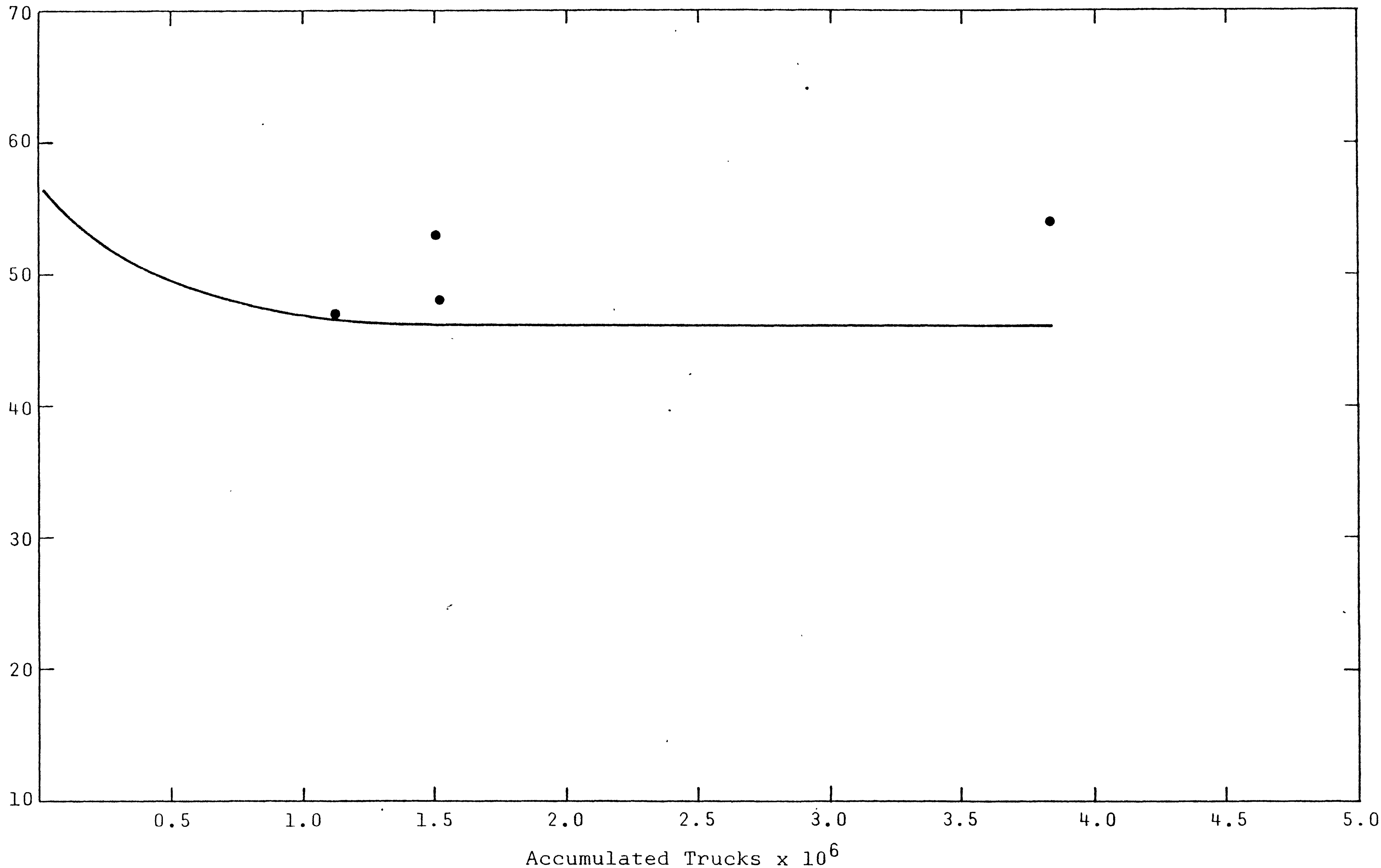

Figure A-21. Massaponax Sand and Gravel

3917

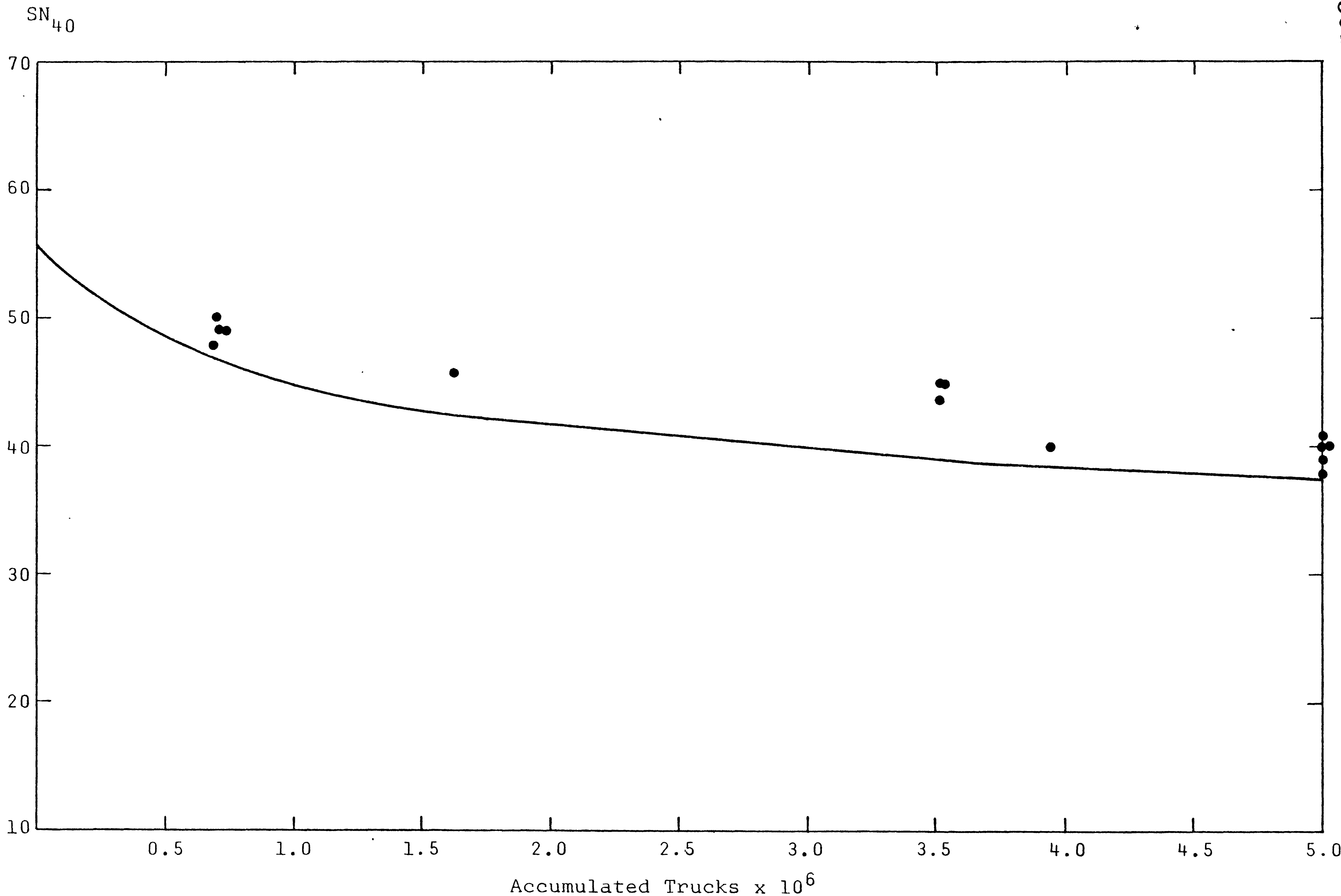

Figure A-22. Mattaponi Sand and Gravel—Duane, Va.

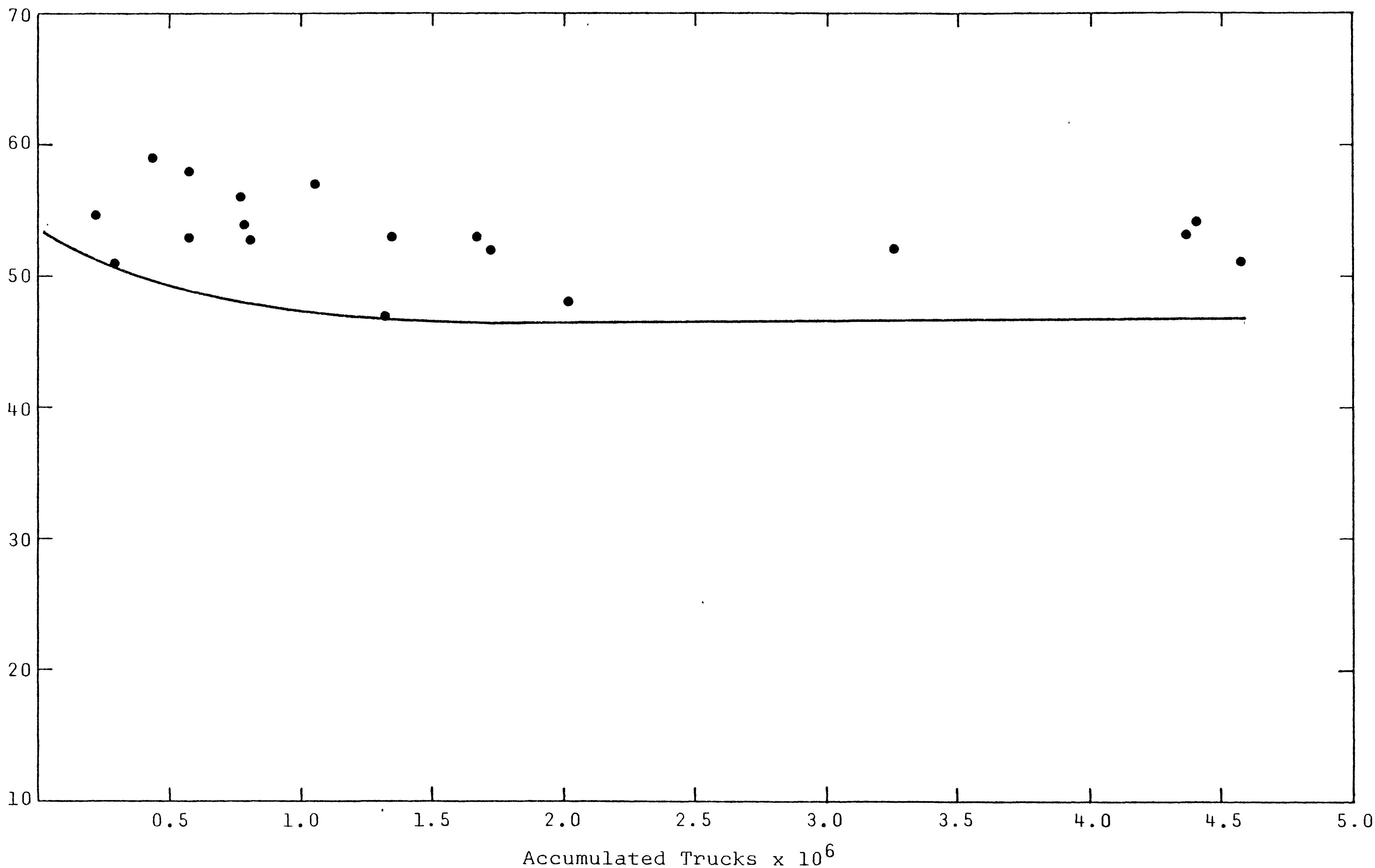

Figure A-23. Newmand Brothers Quarry—Sylvatus

3919

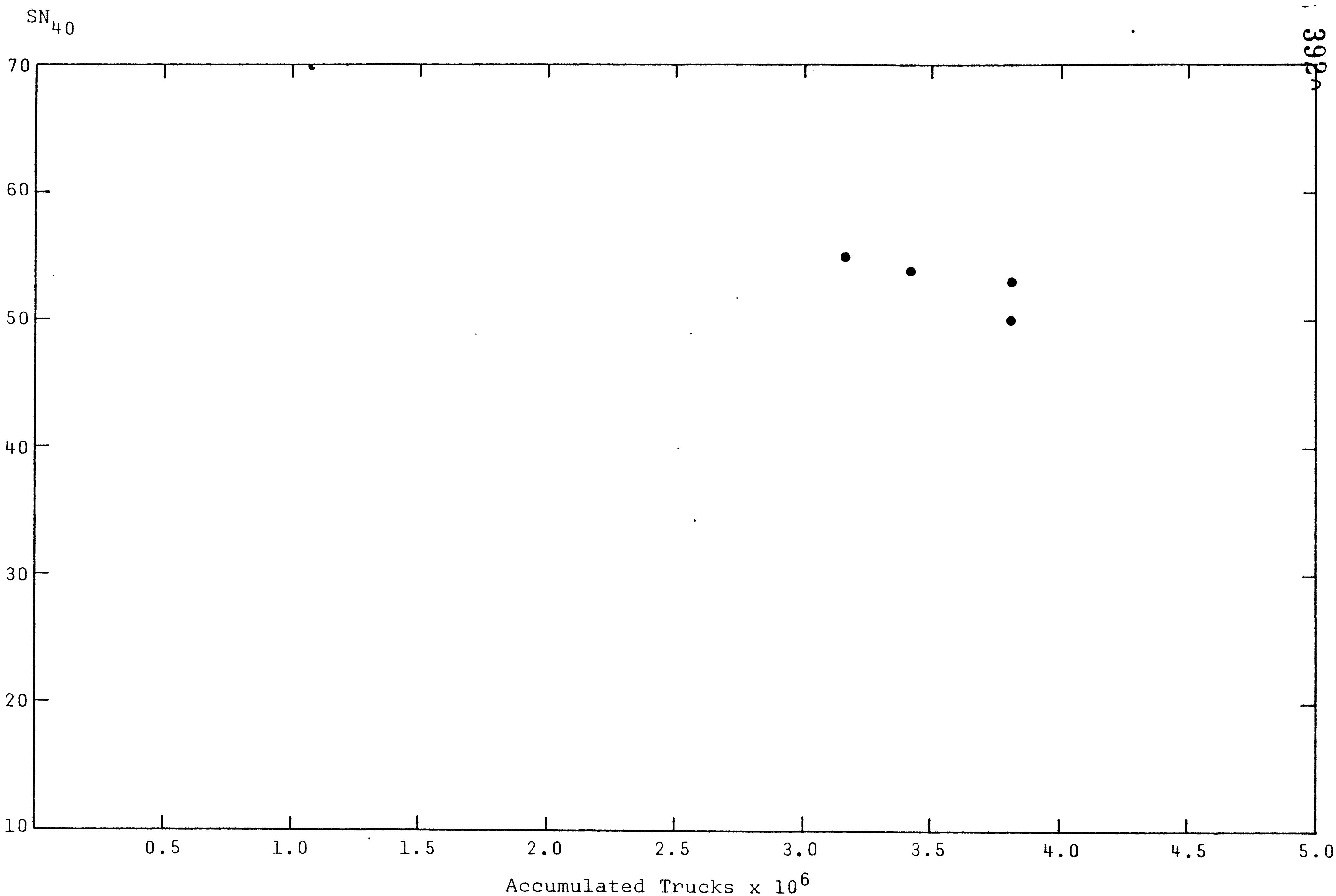

Figure A-24. Port Royal Sand & Gravel—Woodford

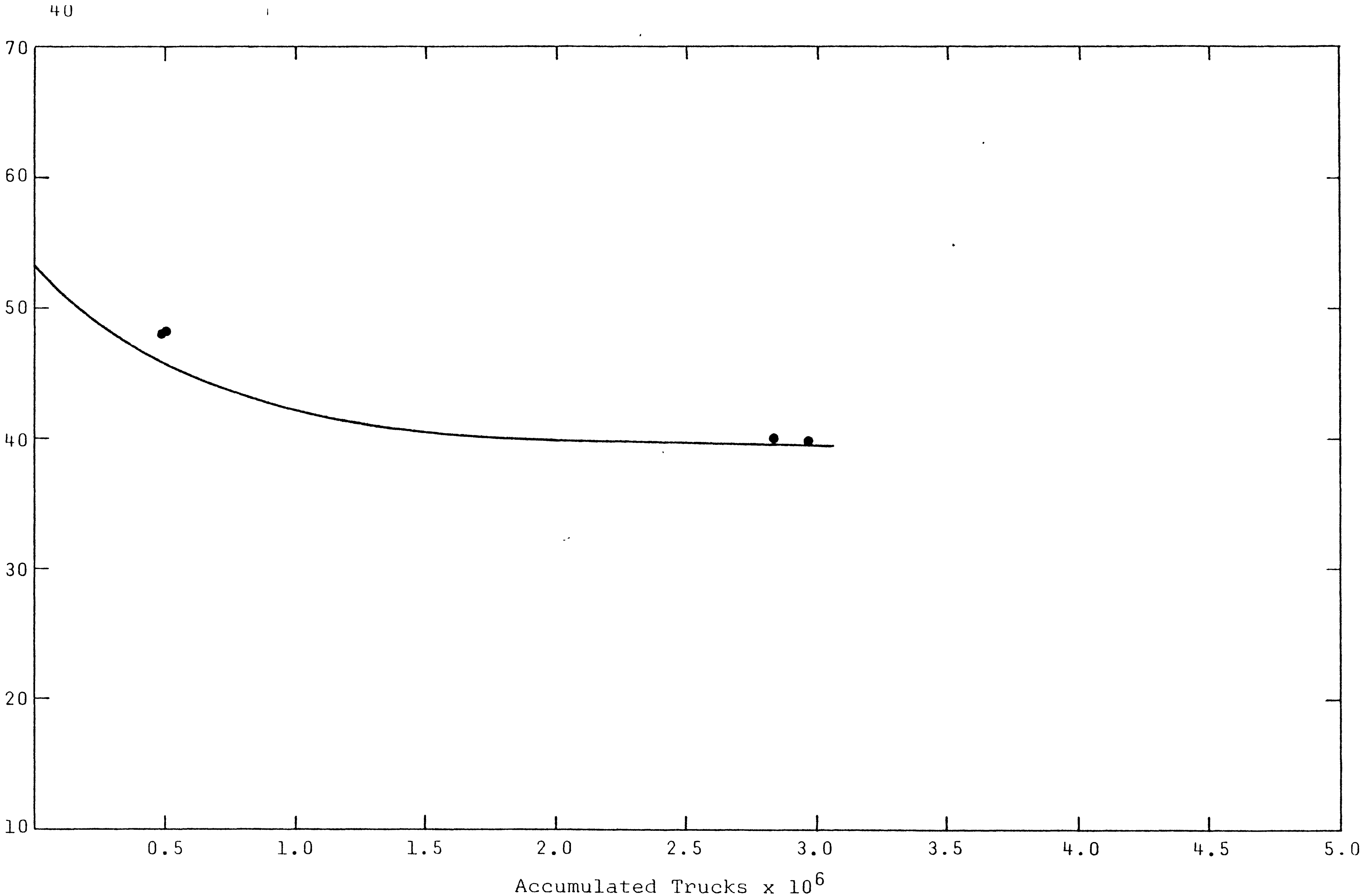

Figure A-25. Richmond Crushed Stone—Oilville

3921

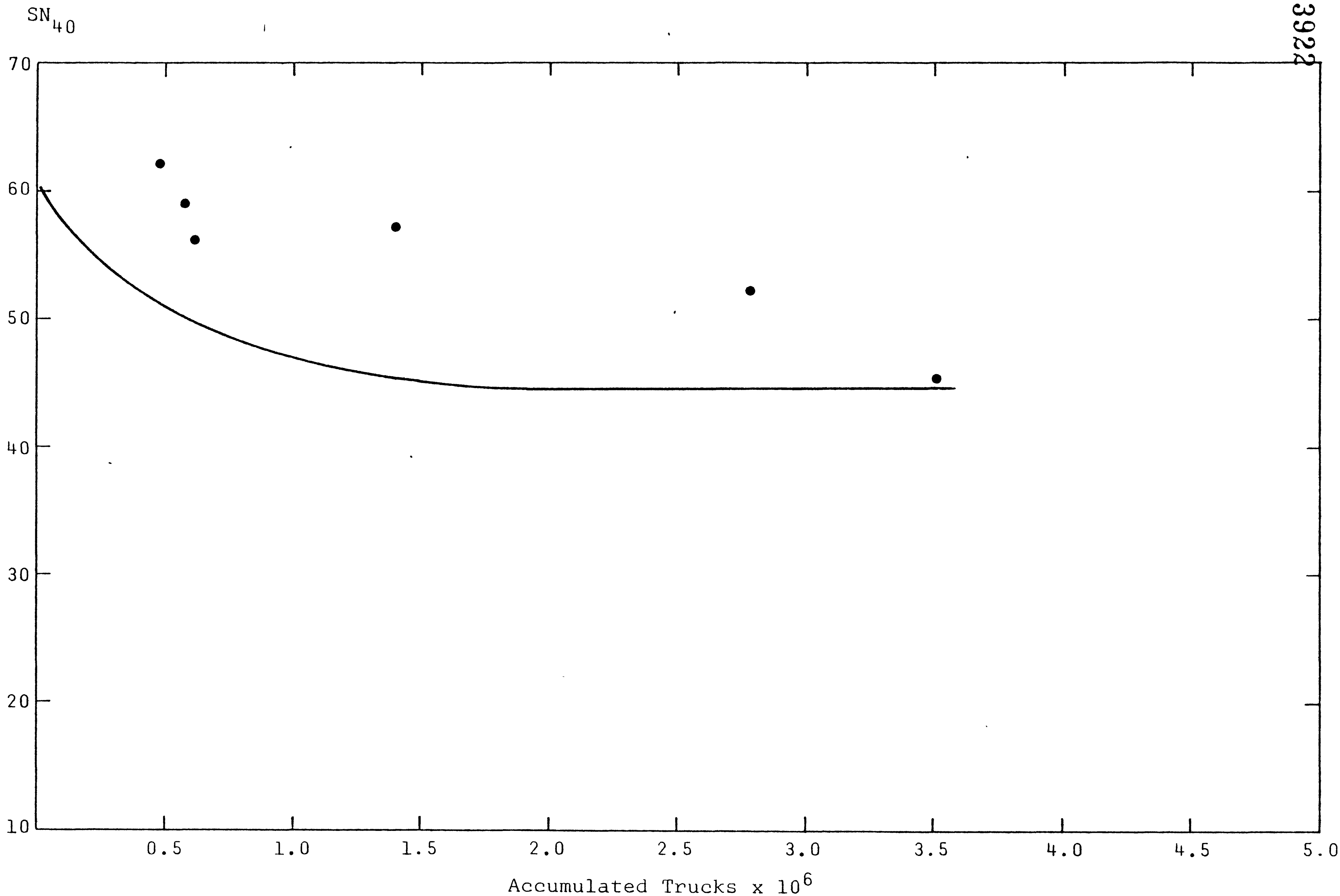

Figure A-26. Riverton Lime and Stone—Riverton

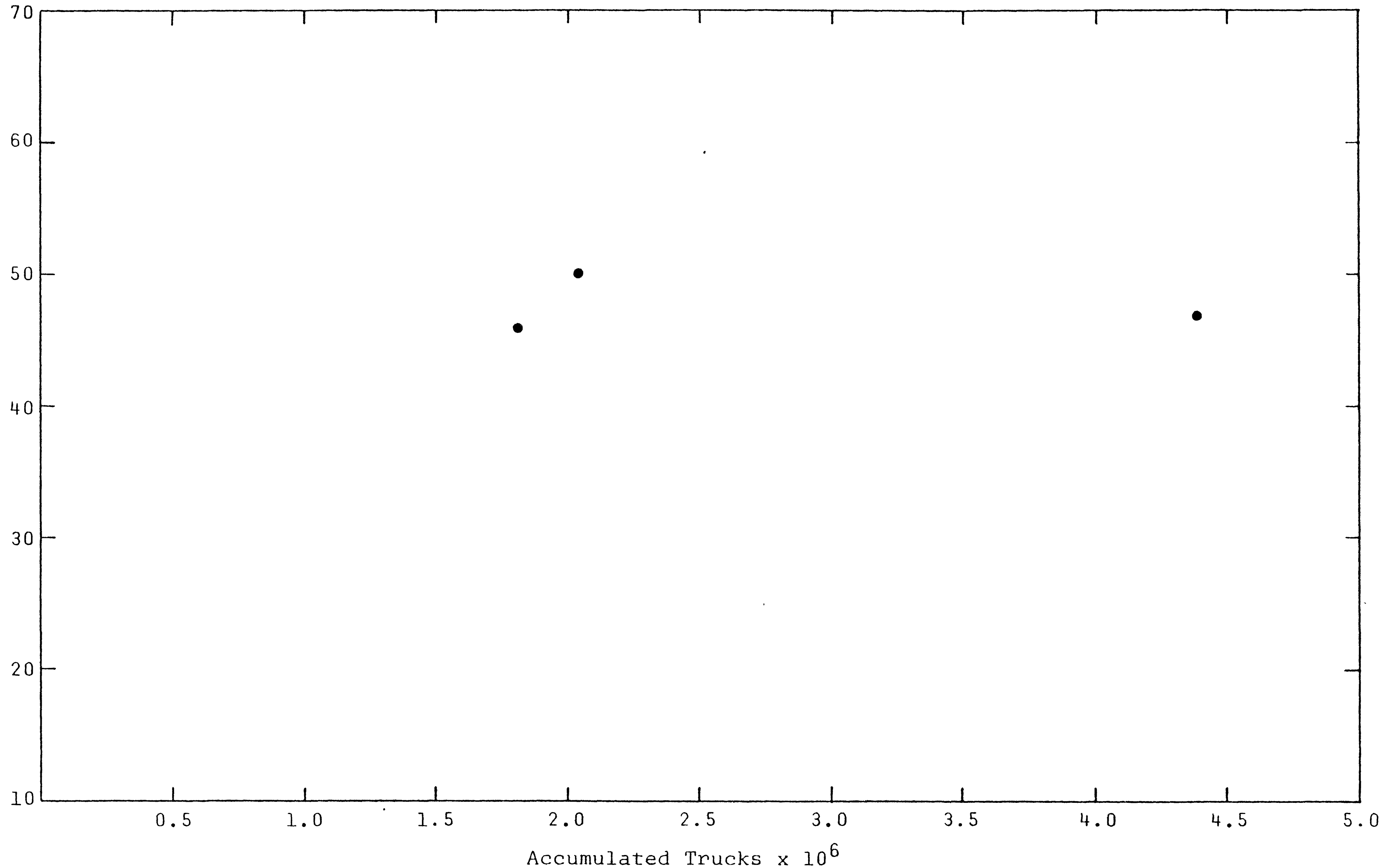

Figure A-27. Rockville Stone—Hylas

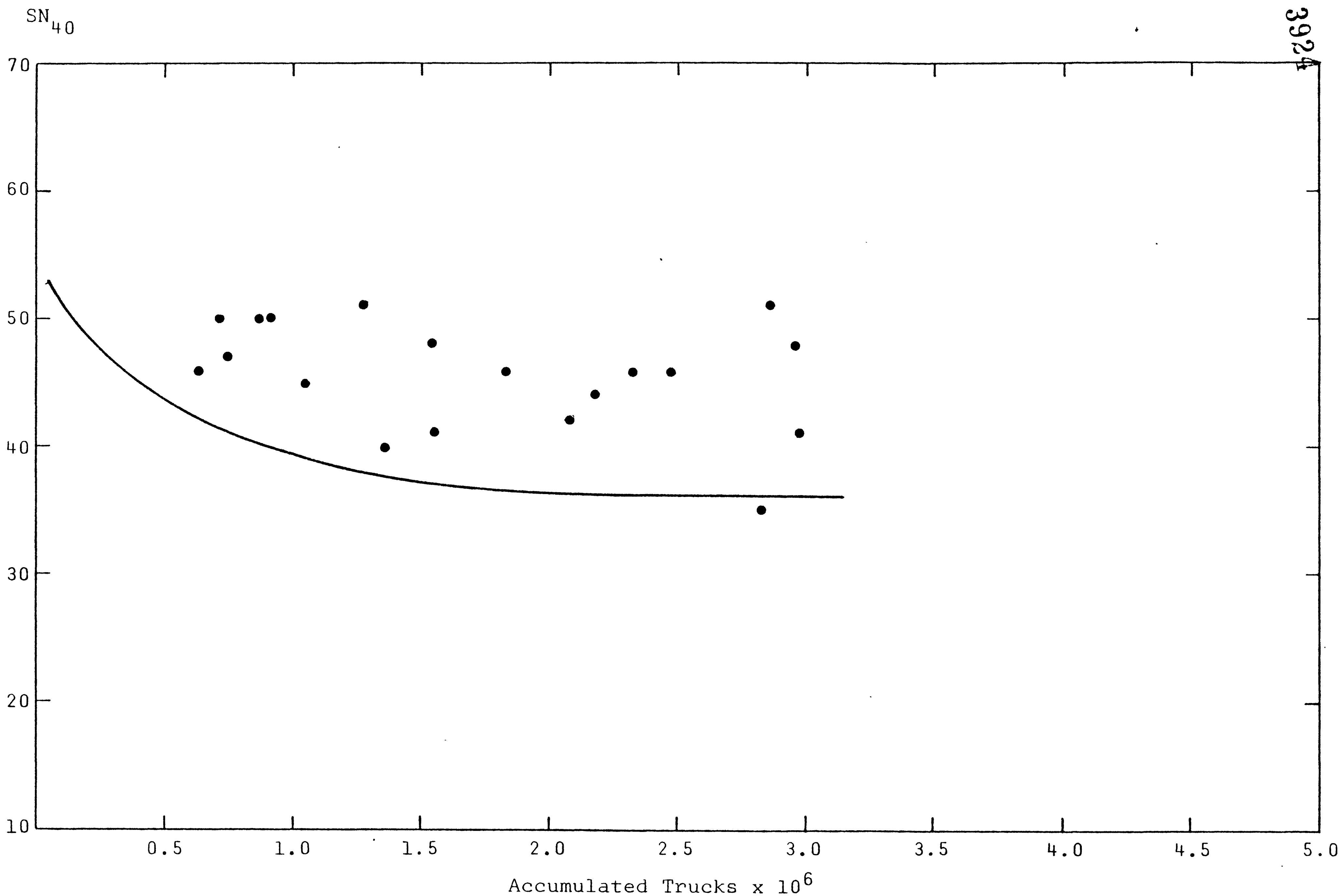

Figure A-28. Rockydale Stone Service—Lynchburg

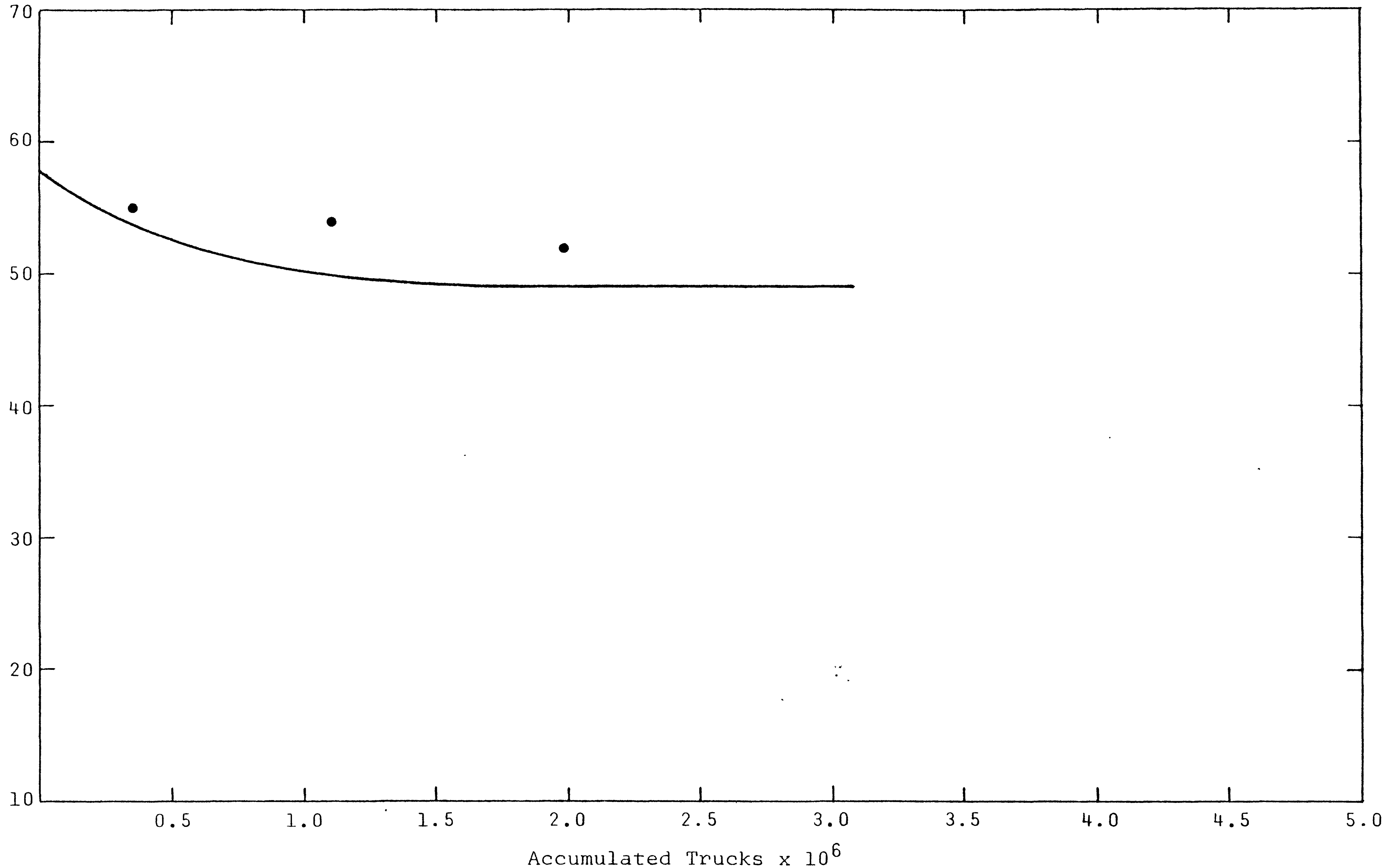

Figure A-29. Salem Stone—Elliston (Gravel)

3925

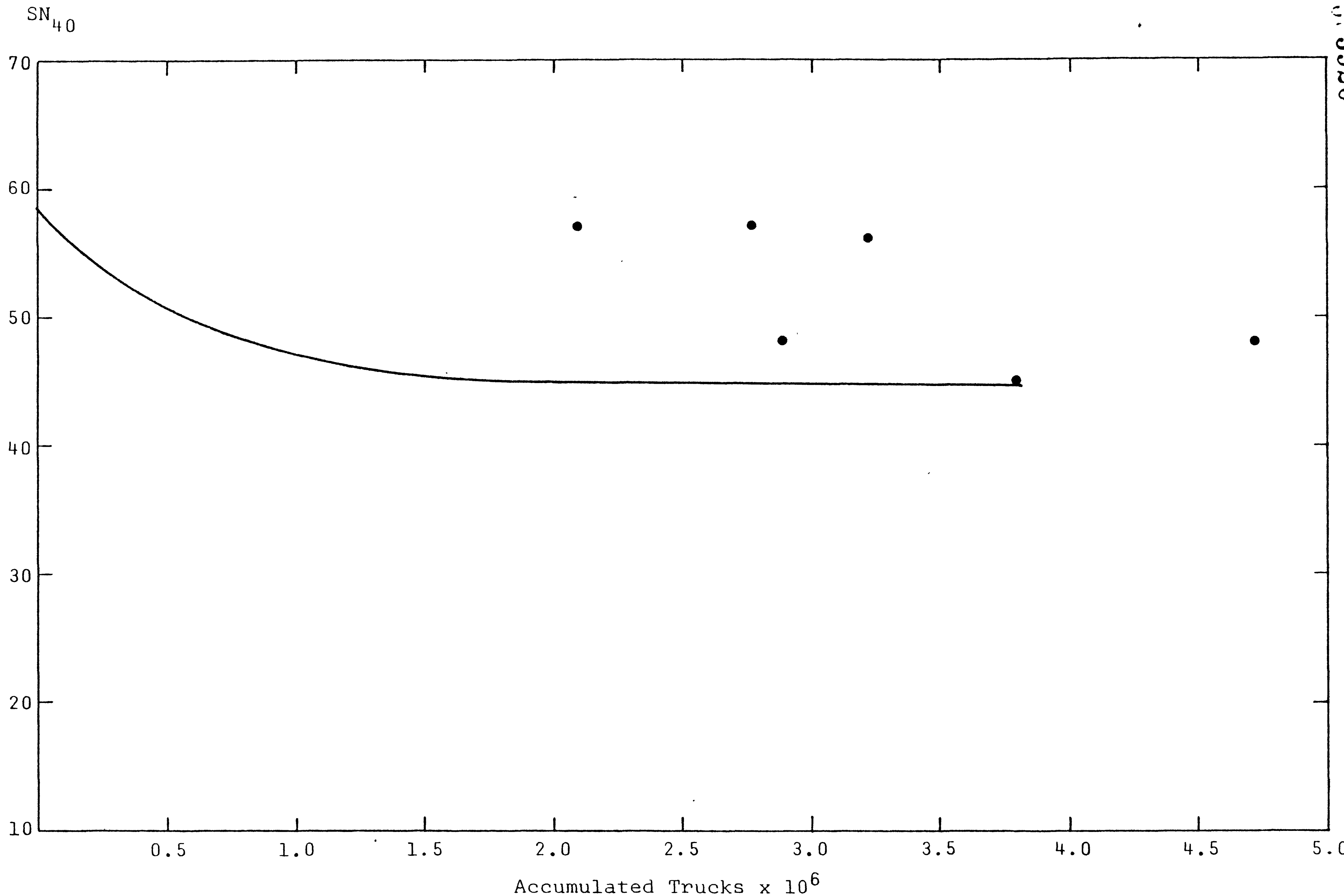

Figure A-30. Sanders Quarry—Warrenton

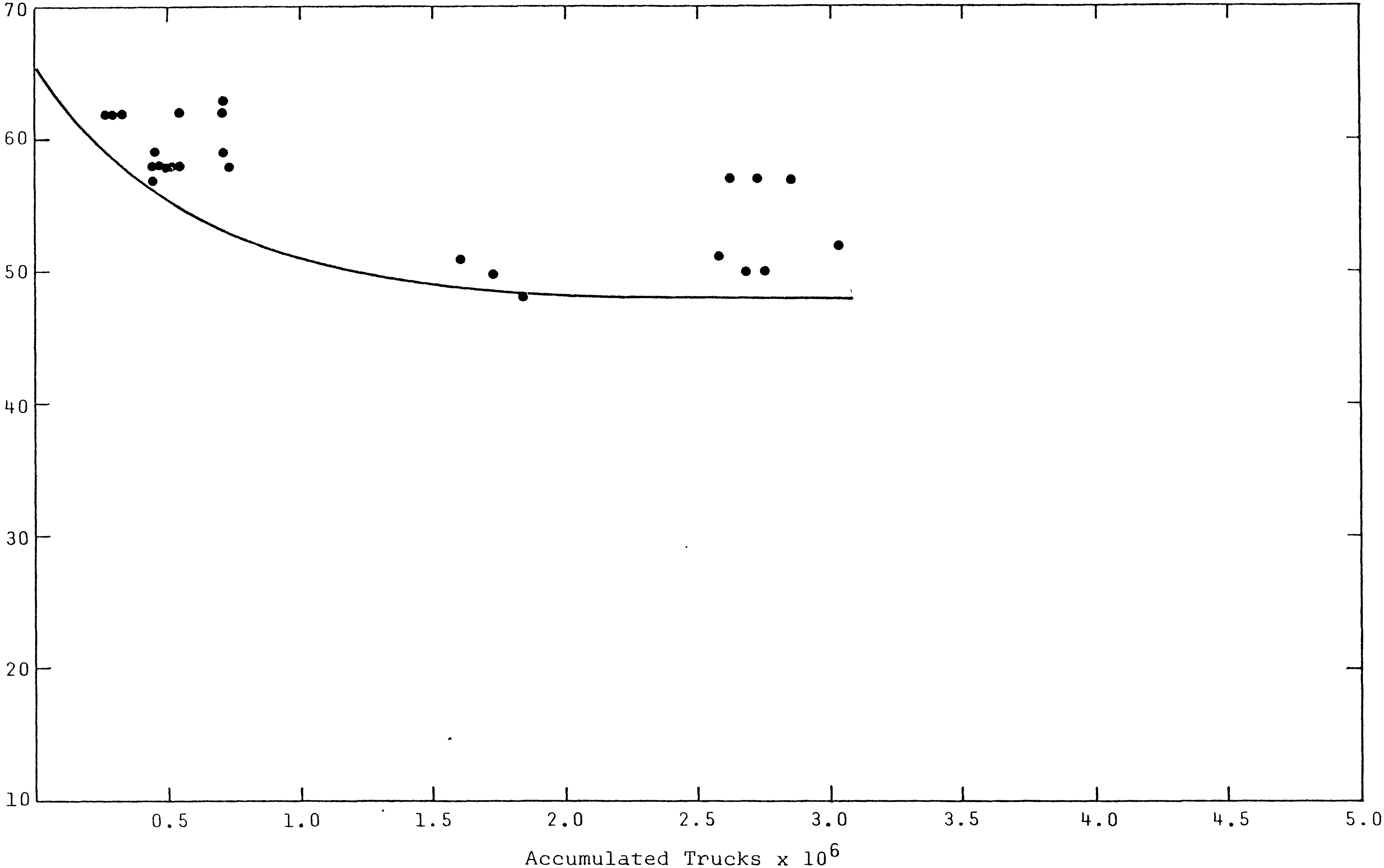

Figure A-31. Shenandoah Sand and Gravel—Shenandoah

3928

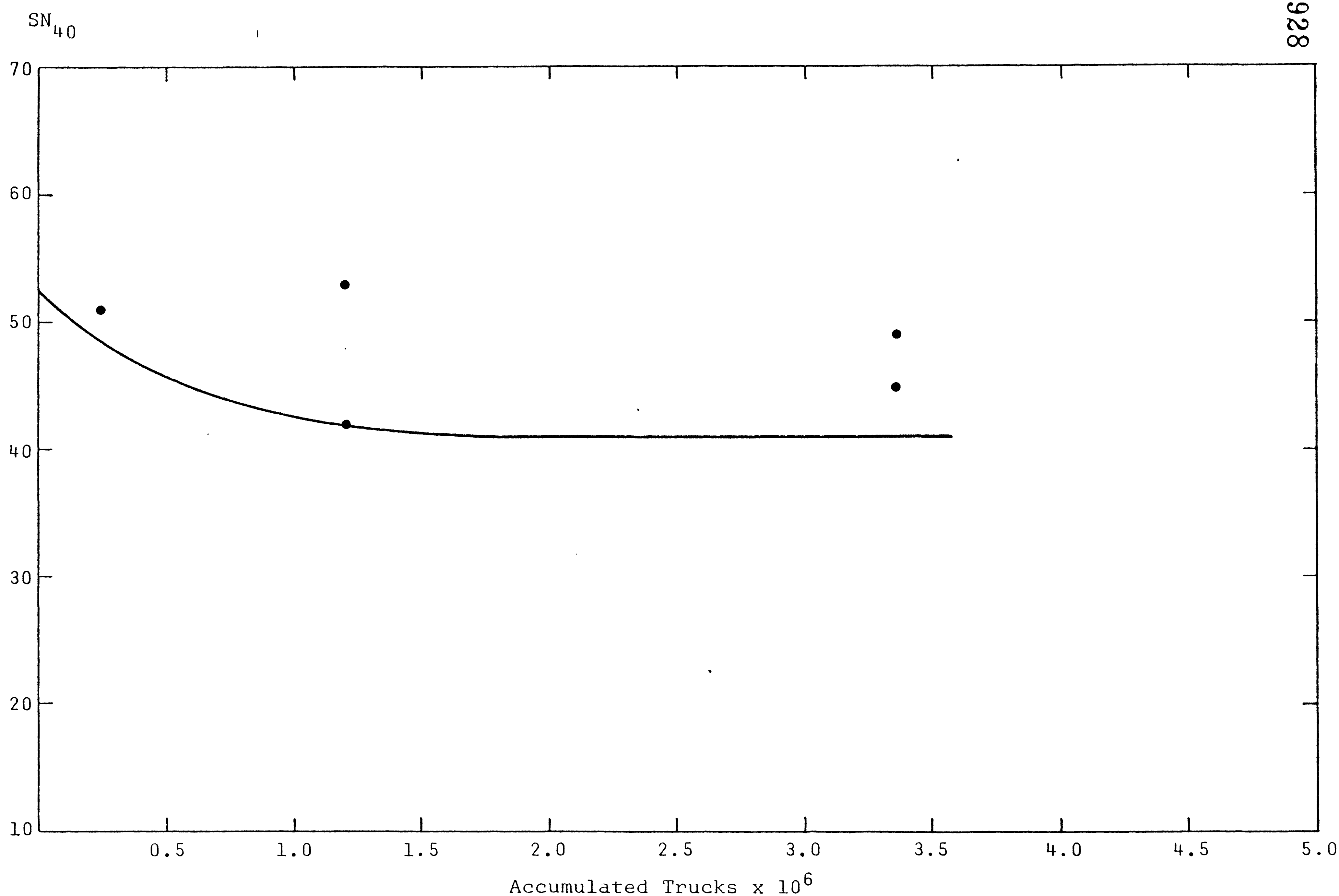

Figure A-32. Solite—Richmond (PCC)

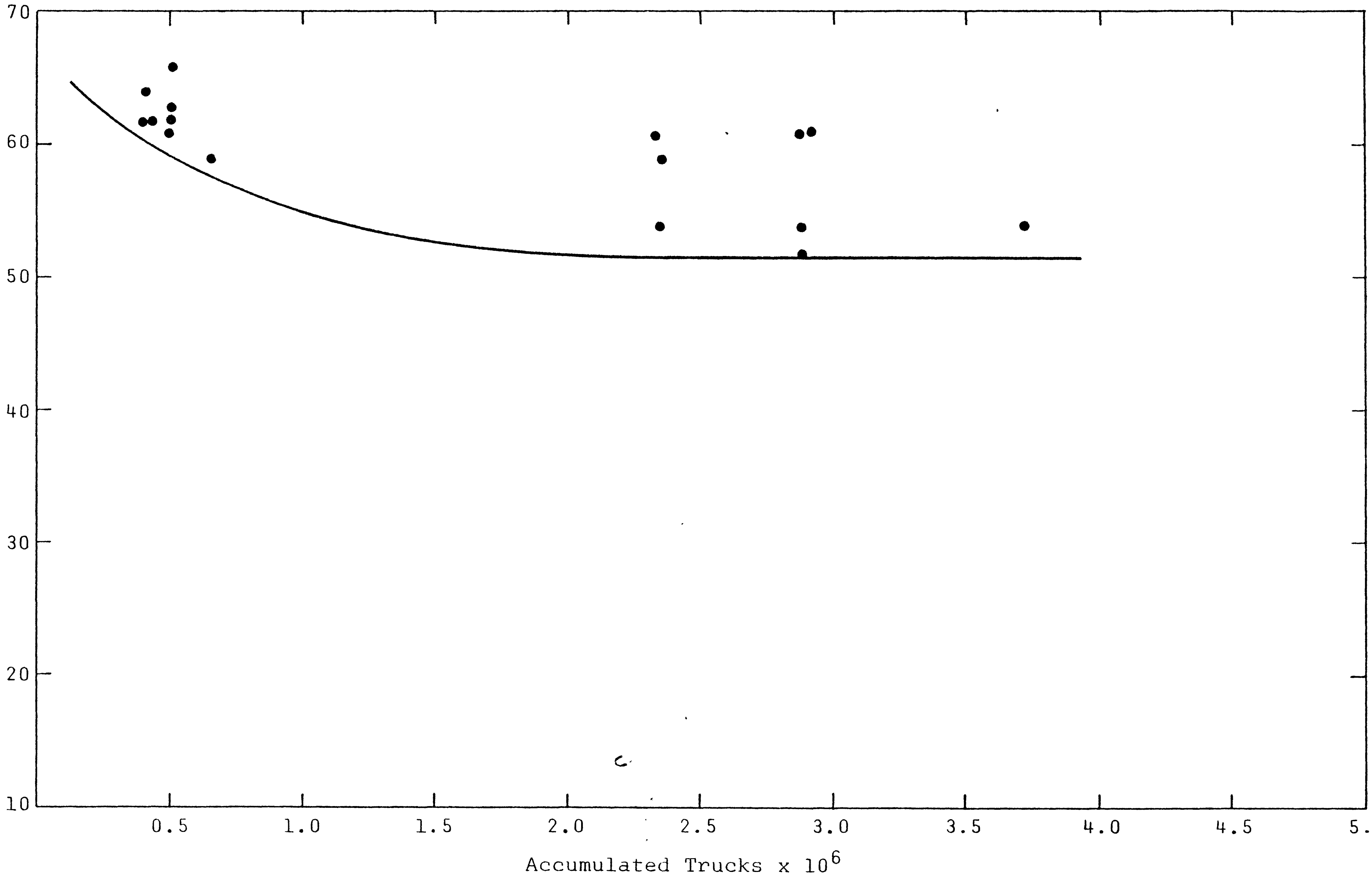

Figure A-33. Southwest Materials—Vesurius

3929

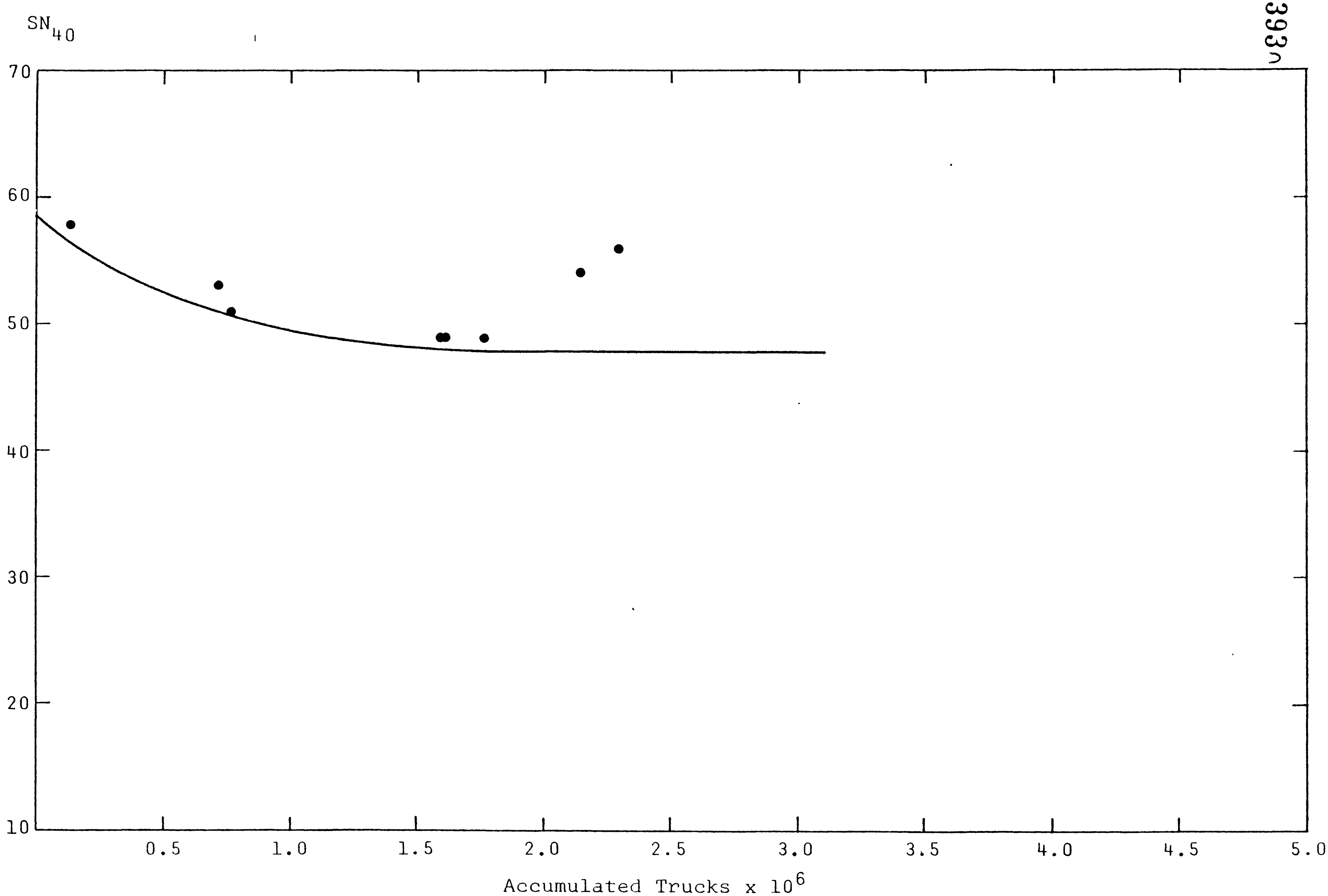

Figure A-34. Superior Stone—Redhill

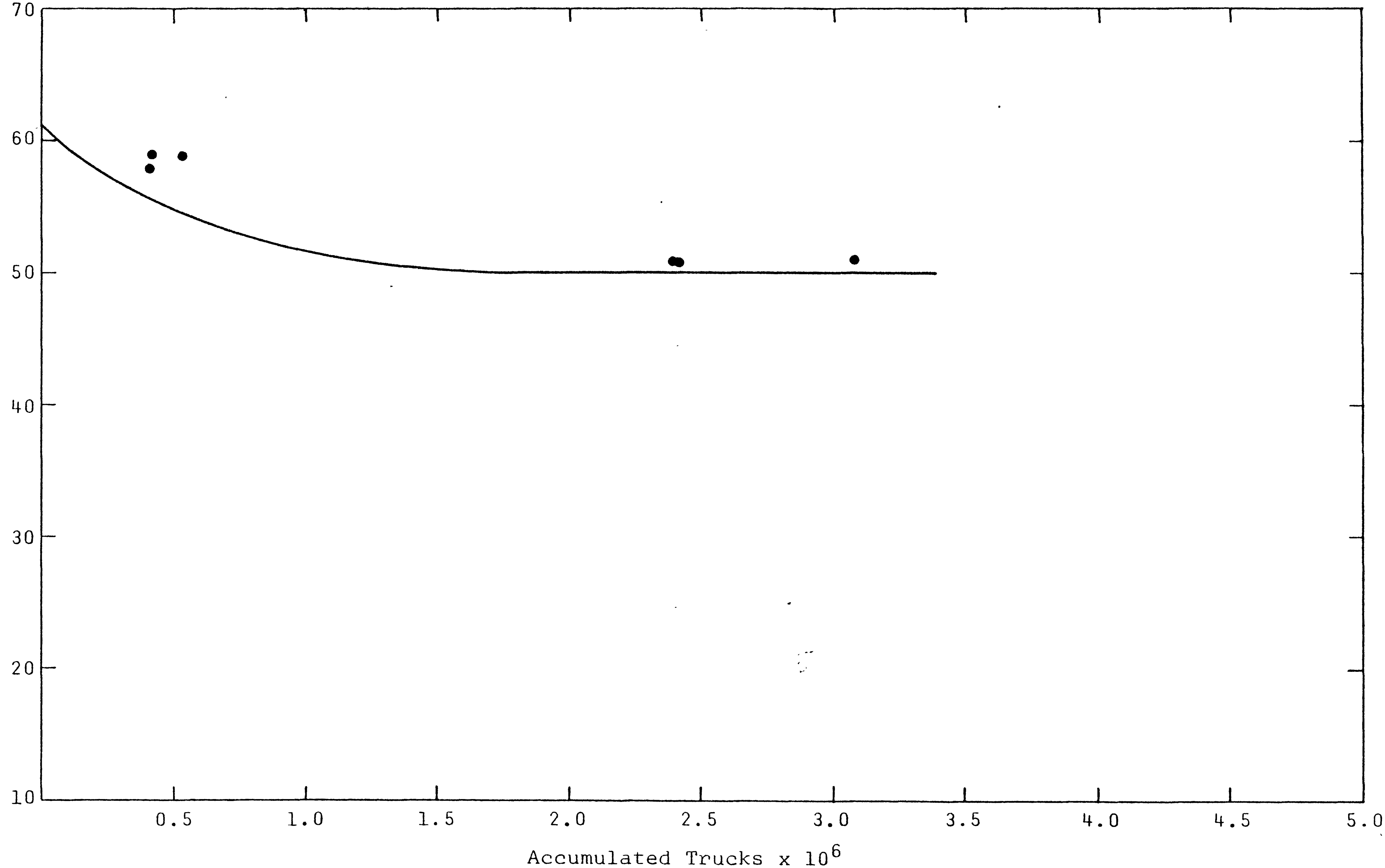

Figure A-35. Superior Stone—Rivanna

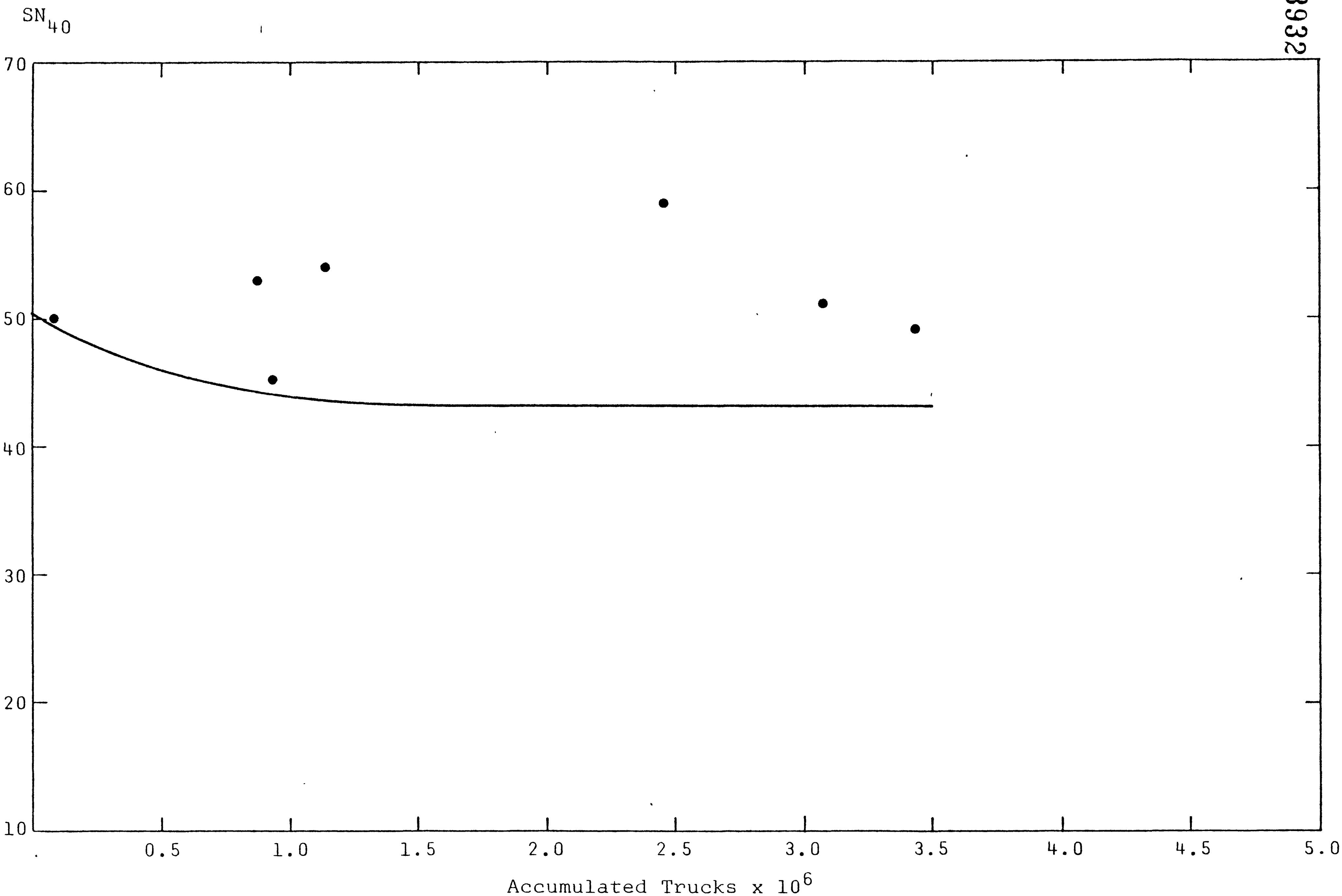

Figure A-36. Tidewater Crushed Stone—Richmond

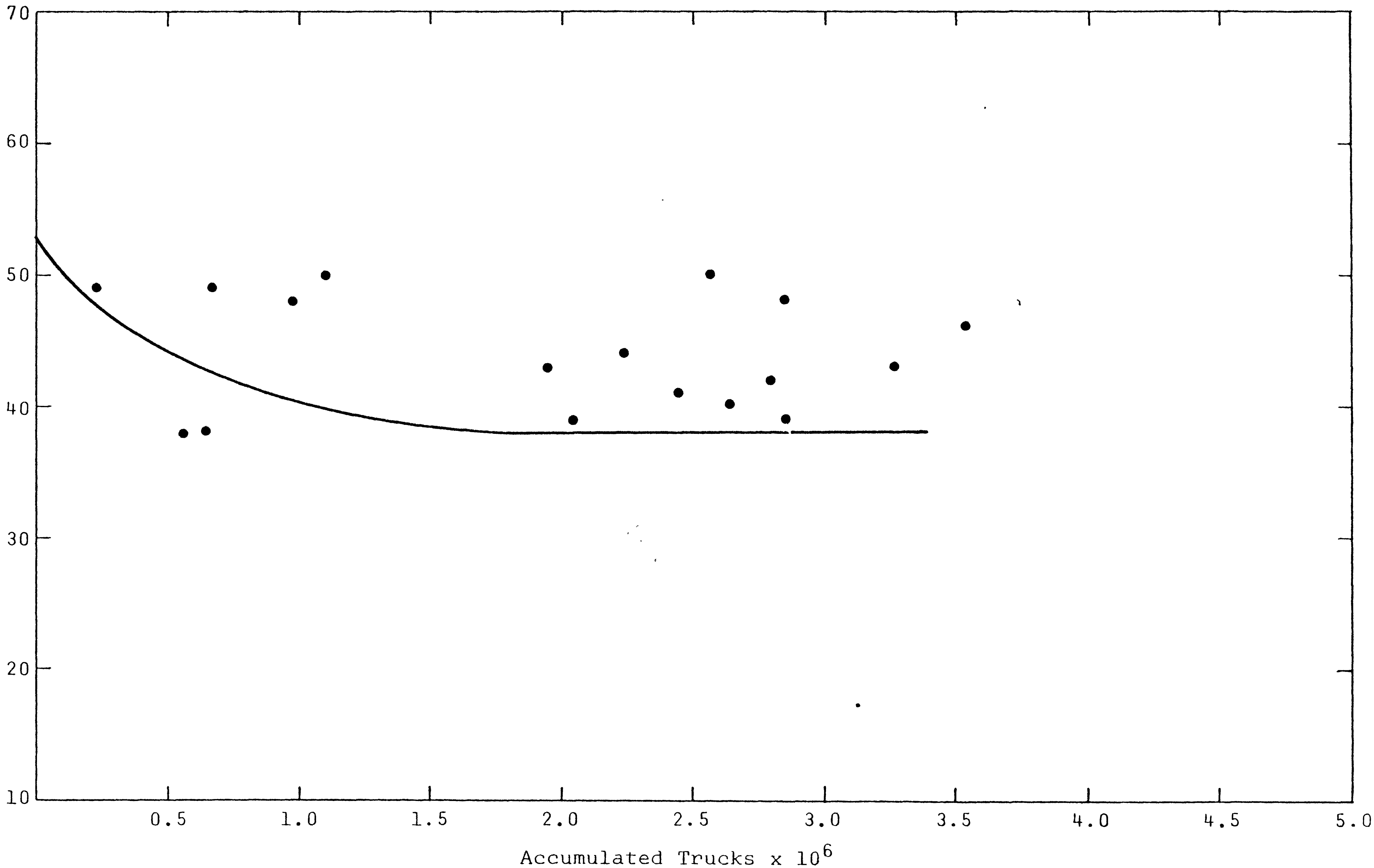

Figure A-37. Trego Stone—Skippers

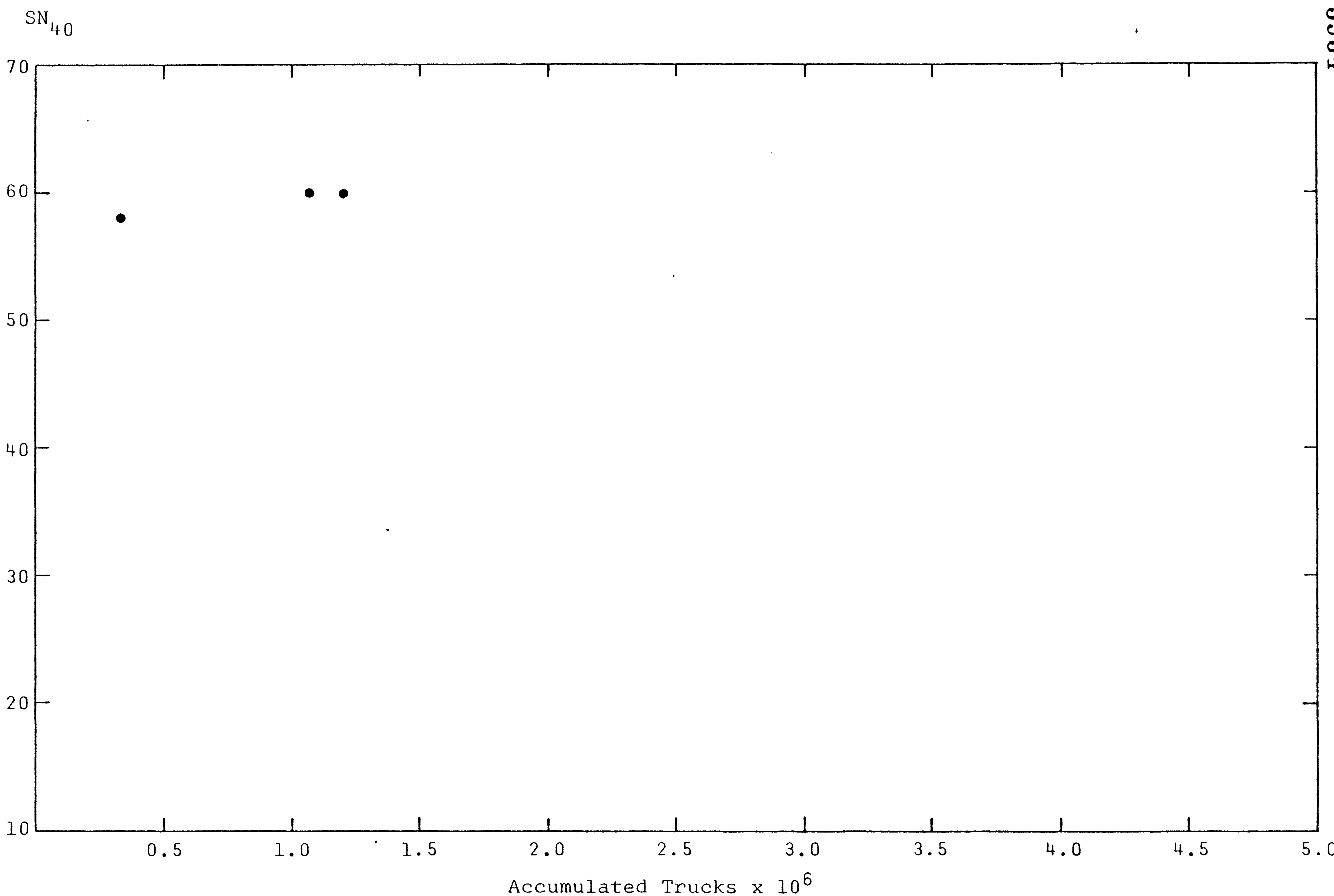

Figure A-38. Tri-City Sand, Johnson City, Tennessee

3934

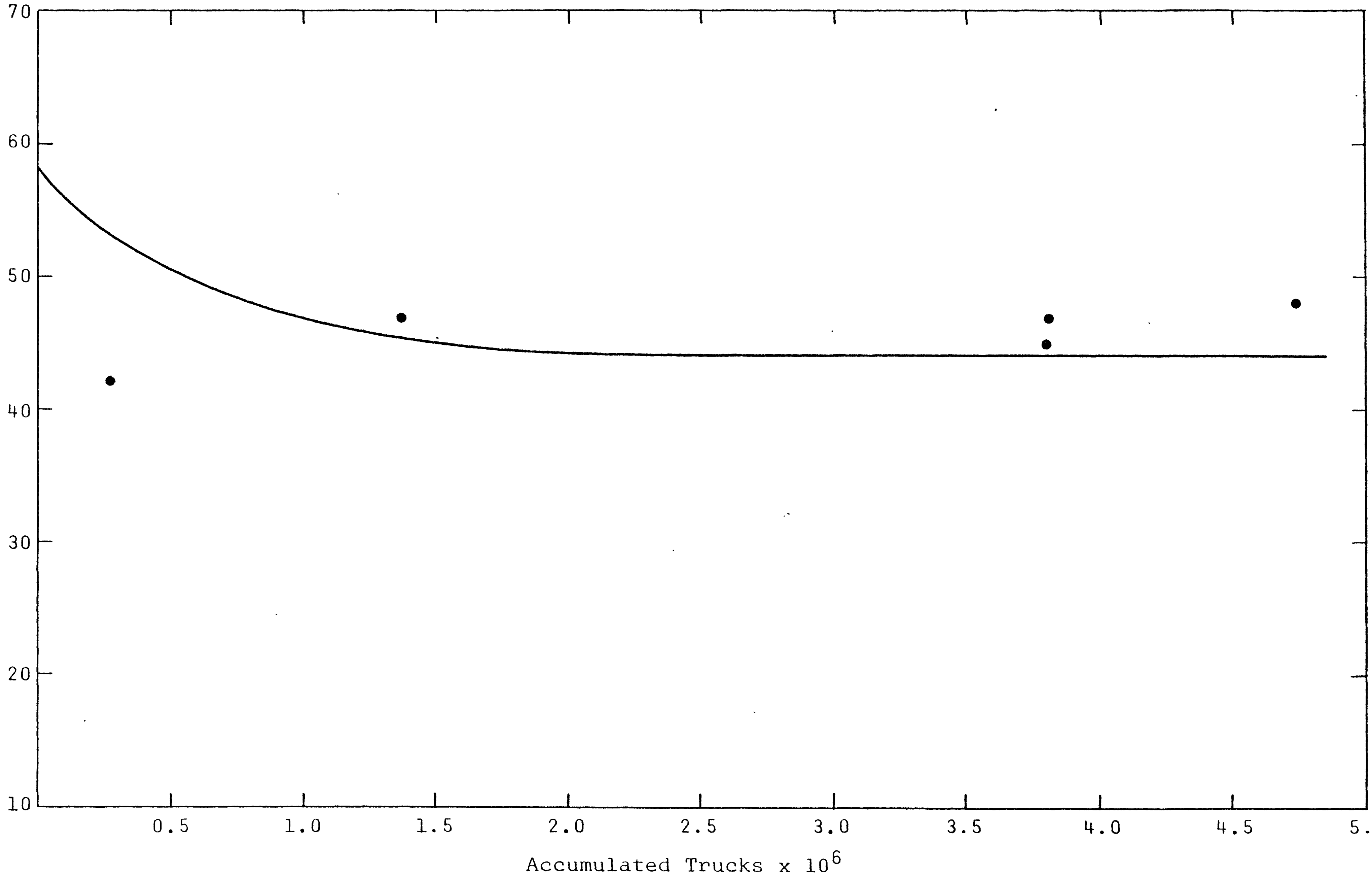

Figure A-39. Virginia Trap Rock—Leesburg

3935

3936

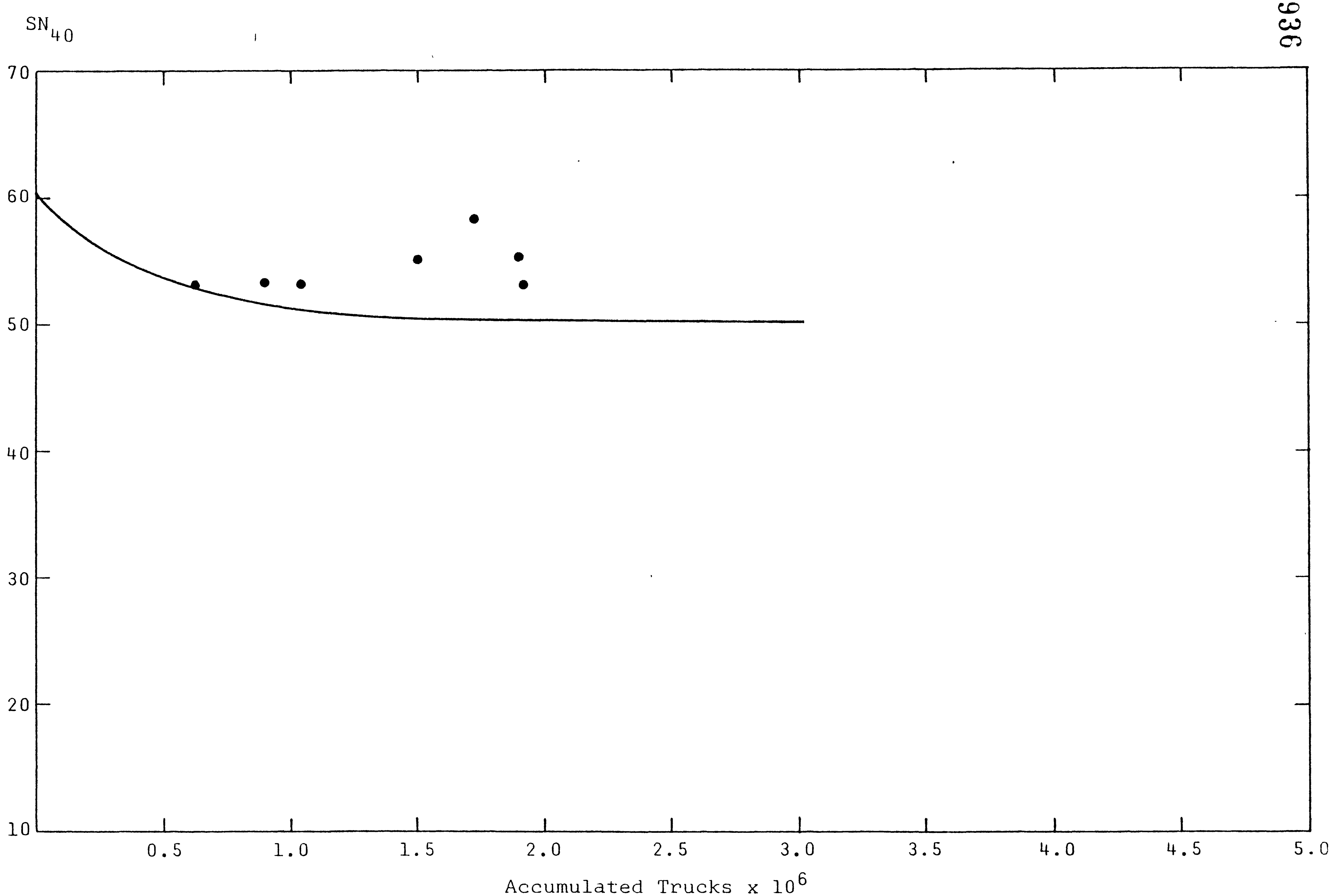

Figure A-40. Vulcan Materials—Chatham

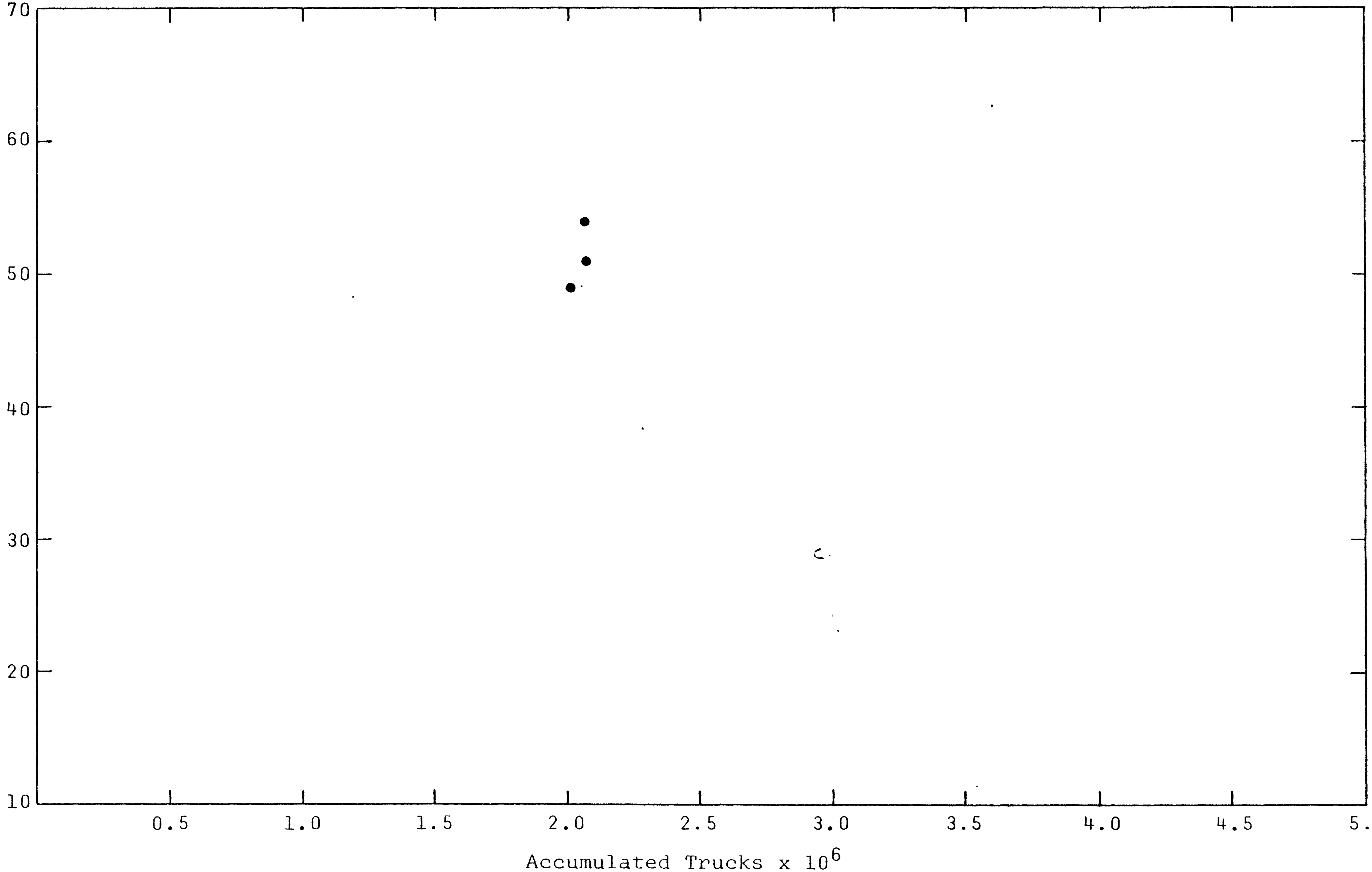

Figure A-41. Vulcan Materials—Danville

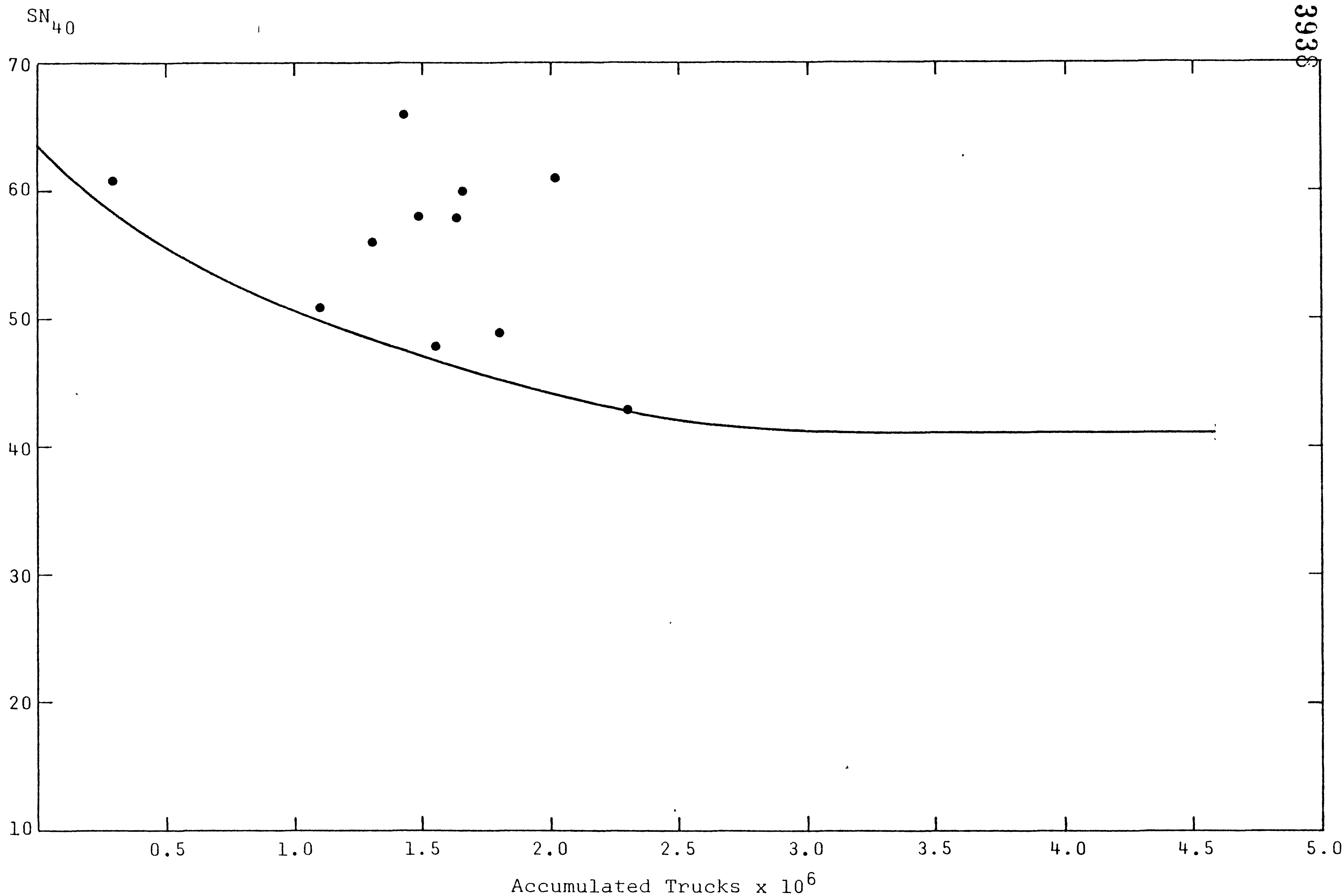

Figure A-42. Vulcan Materials—Erwin, Tennessee

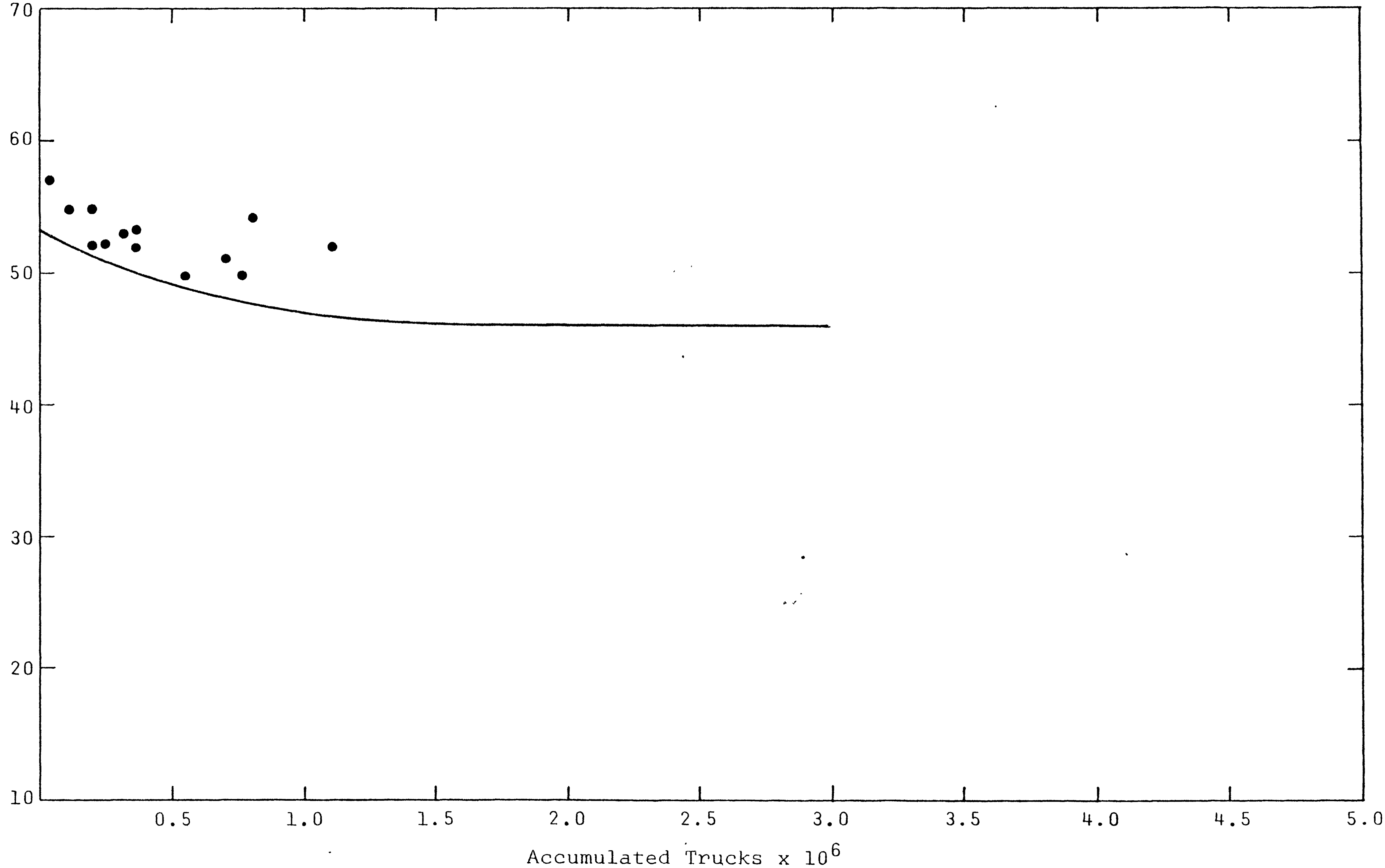

Figure A-43. Vulcan Materials—Lawrenceville

3939

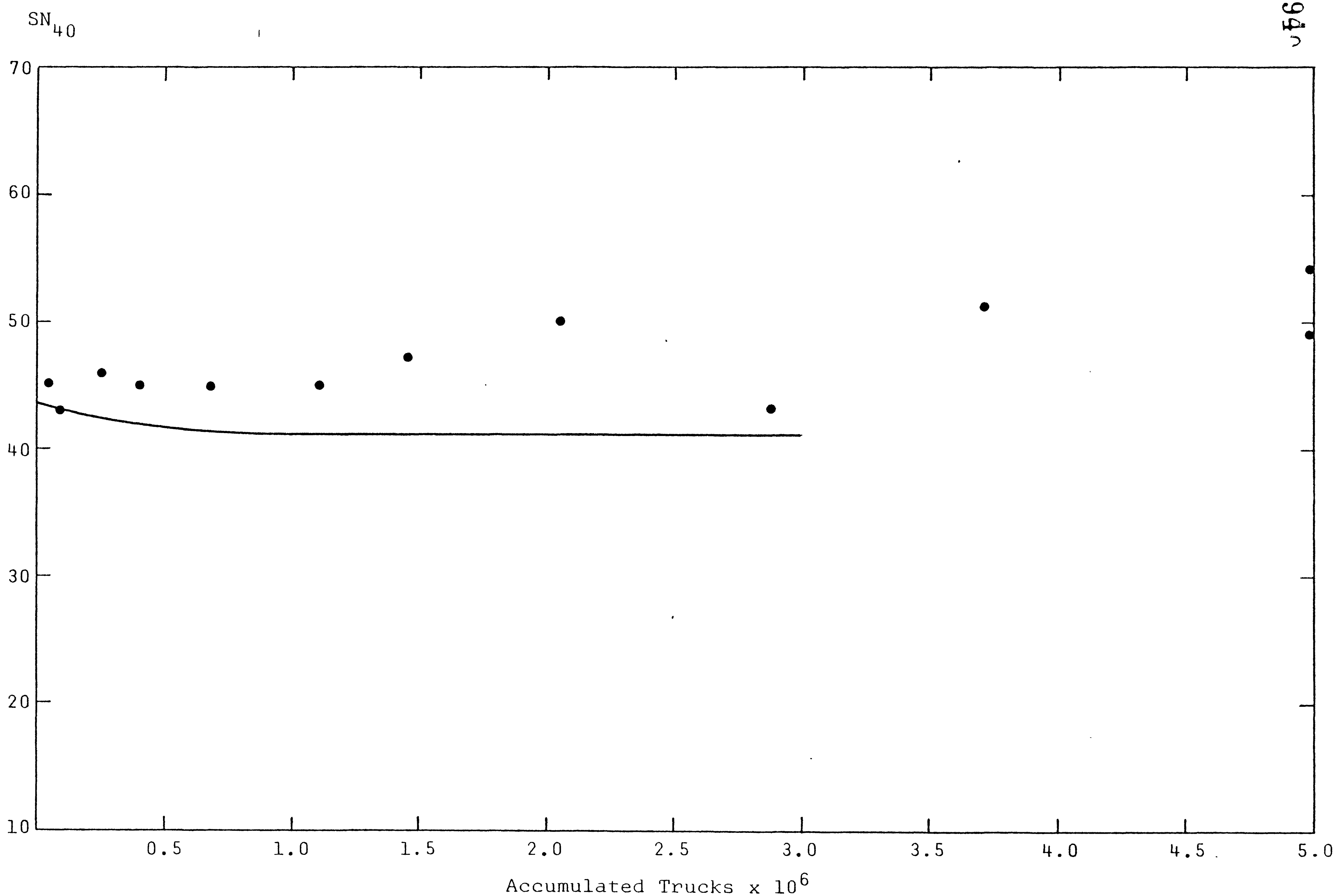

Figure A-44. Vulcan Materials—Manassas

40

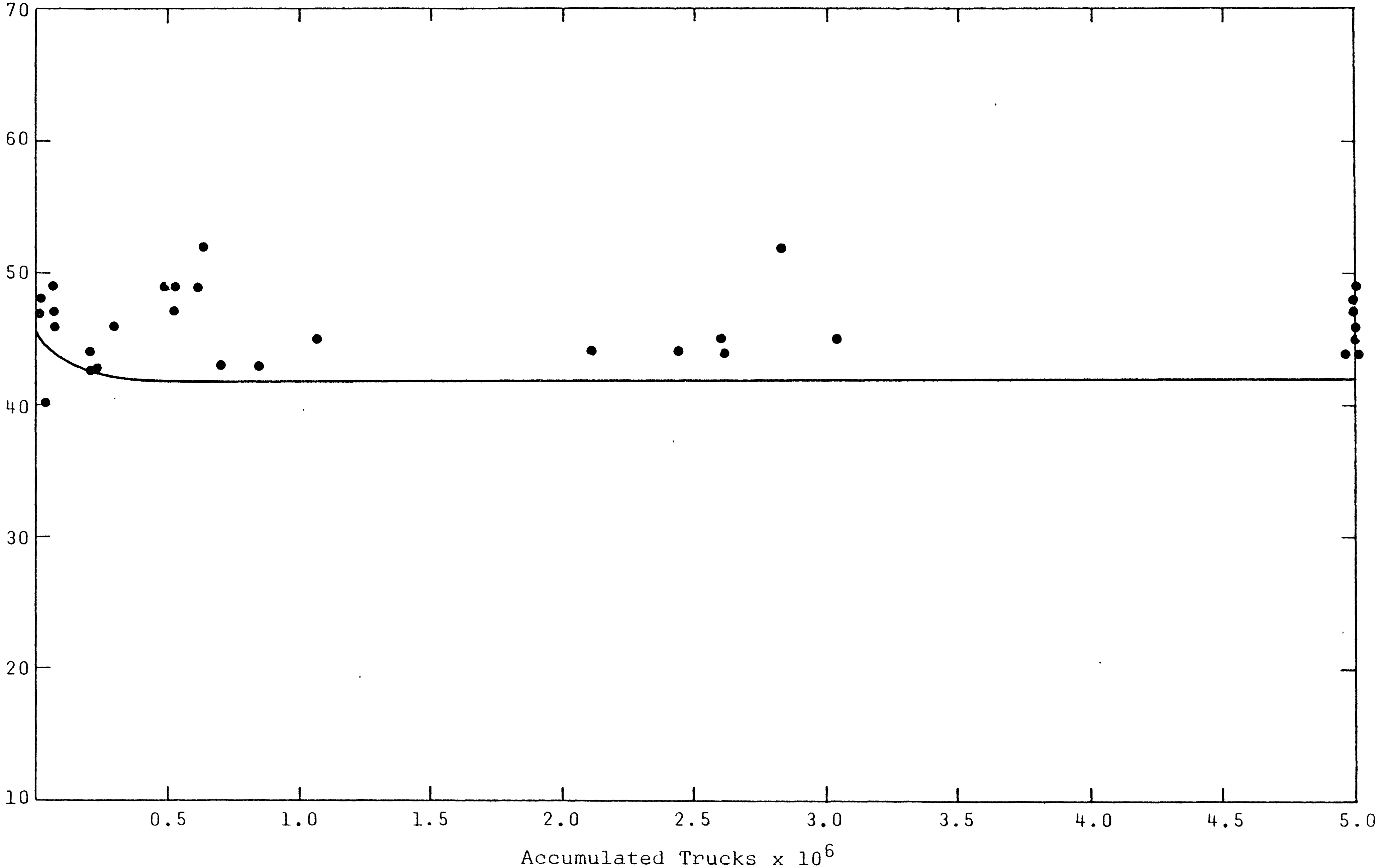

Figure A-45. Vulcan Materials—Occoquan

3941

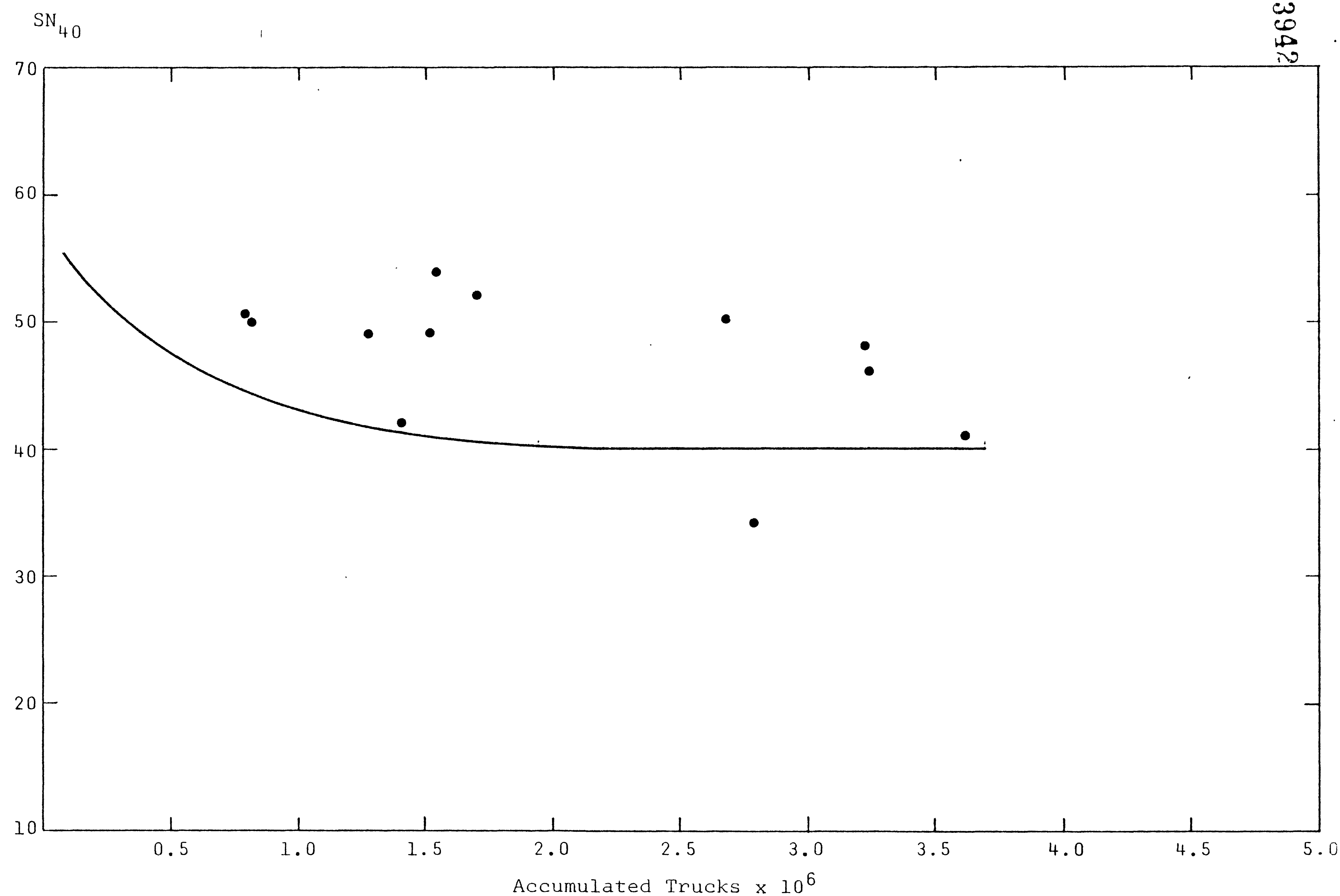

Figure A-46. Vulcan Materials—South Boston

3942

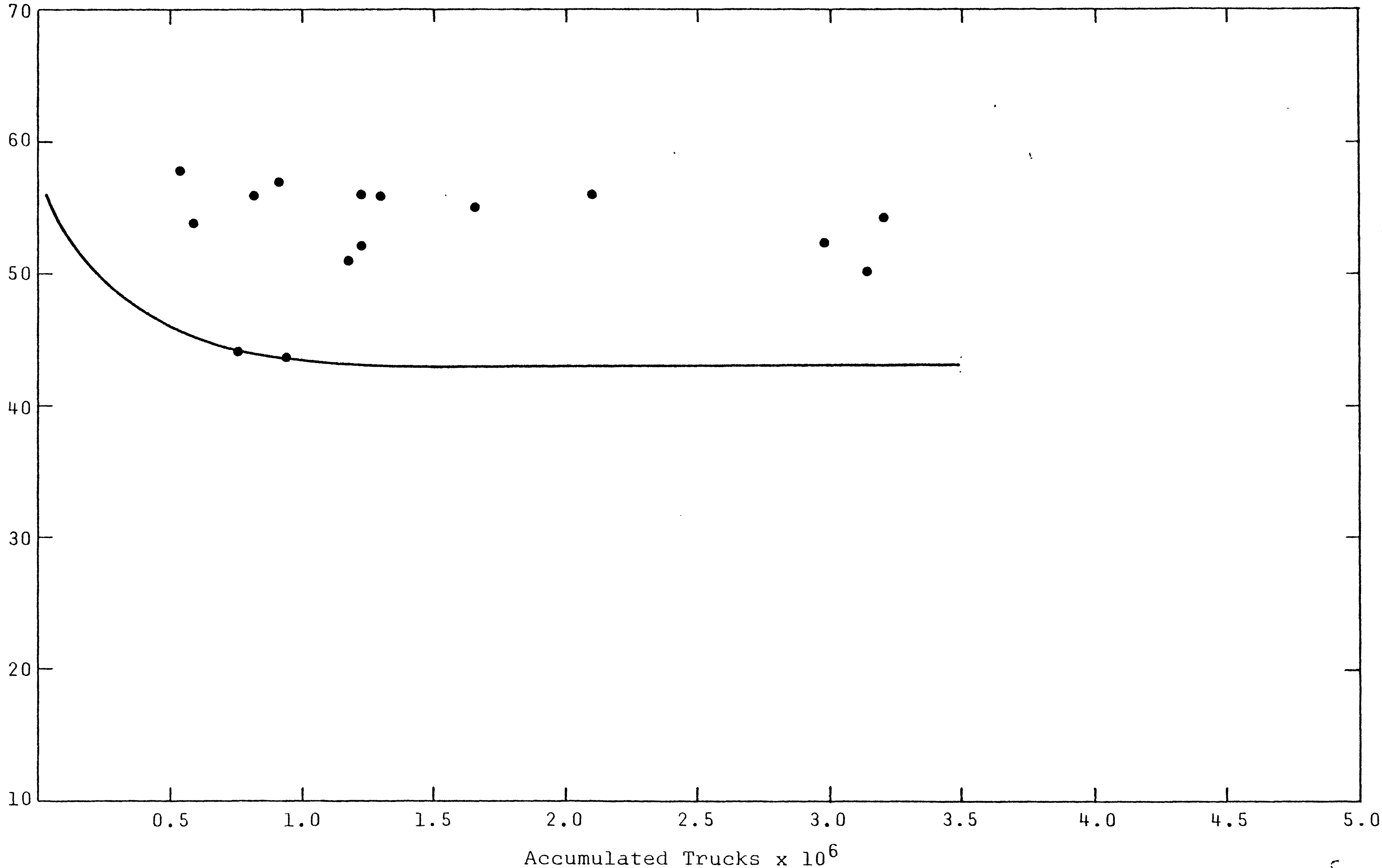

Figure A-47. West Sand and Gravel—Richmond Gravel

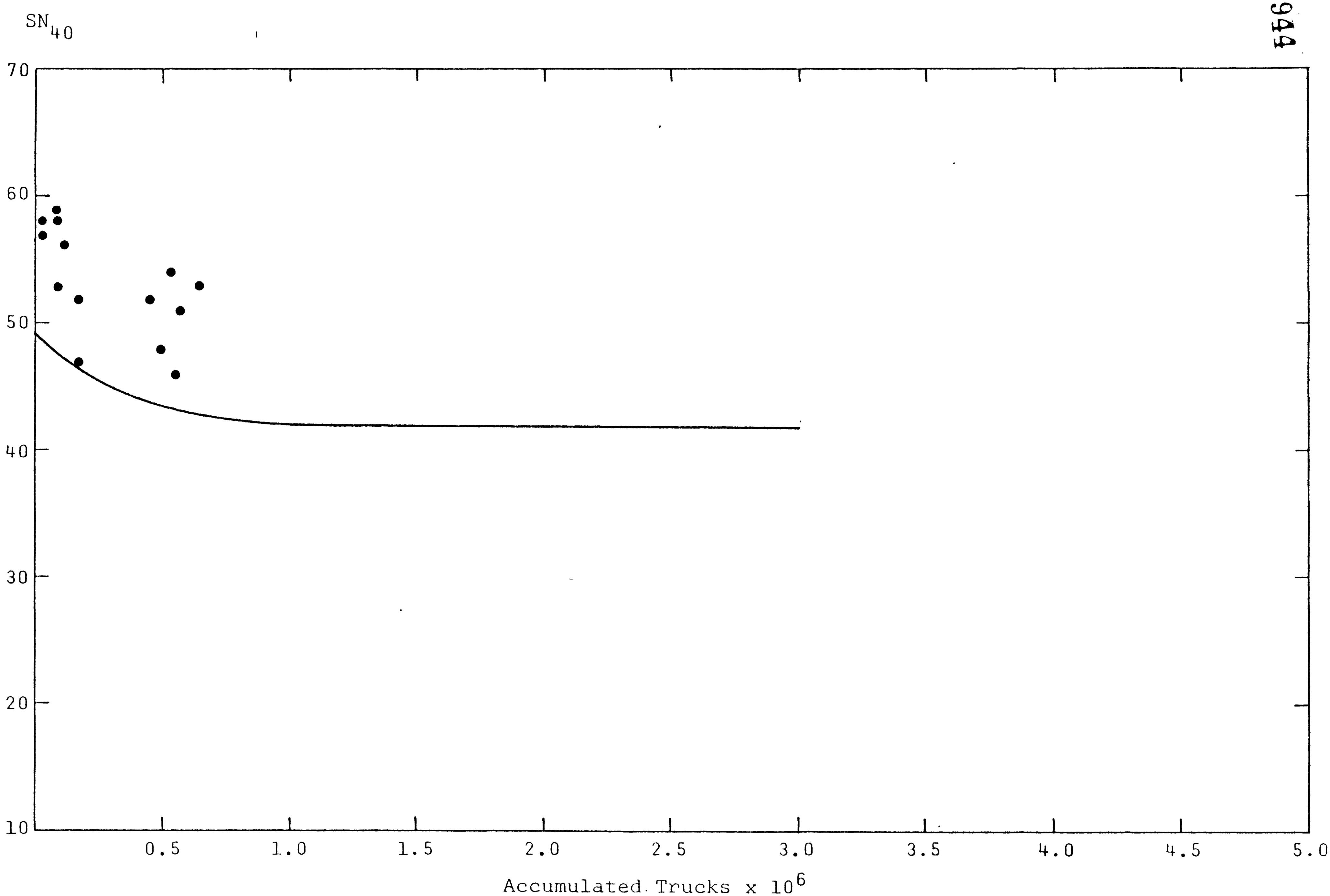

Figure A-48. West Sand & Gravel—Richmond (PCC)