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Paper E 12

WATER TURBIDITY DETECTION USING ERTS-1 IMAGERY¹

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1.0

ABSTRACT

ERTS-1 images of two federal reservoirs in Kansas exhibit good correlation with suspended load. The major reservoirs in Kansas, as well as in other Great Plains states, are playing increasingly important roles in flood control, recreation, agriculture, and urban water supply. Satellite imagery may prove useful for acquiring timely low cost water quality data required for optimum management of these fresh water resources.

2.0

INTRODUCTION

The dominant limnological feature of the Great Plains today takes the form of reservoirs constructed by the U.S. Army Corps of Engineers and the U.S. Bureau of Reclamation. The primary influence on the reservoir ecosystem is the suspended material and chemicals carried in by streams and rivers. The authors are studying ERTS images of Kansas reservoirs to determine the feasibility of monitoring these water quality indicators by satellite. The reservoirs throughout the state, which should be representative of most Great Plains reservoirs, are located in a variety of physiographic regions such as the glaciated region in the northeast, the valleys and scarps in the southeast, the dissected plateau and alluvial plains areas in central Kansas, and the high planes in the west.

Two reservoirs, Perry and Tuttle Creek, have been singled out for close study. Approximately ten water samples from each reservoir are collected during each cloud-free ERTS overpass and analyzed for concentrations of inorganic suspended and dissolved solids, organic suspended and dissolved solids, chlorophyll, potassium, phosphate, and nitrate ions. In addition, secchi disc and temperature measurements are taken at each sampling station. The two reservoirs are distinct in terms of adjacent outcropping rocks and land use. Perry drains

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a recently glaciated region in the cornbelt of eastern Kansas. Tuttle Creek drains the Flint Hills area to the west which is outcropping Cretaceous and Permian rock. The dominant land use is seasonal grazing and small grains. A later phase of this project will be to test any predictive relations derived from Perry and Tuttle Creek on other reservoirs in Kansas.

Kansas reservoirs are typically shallow and thus are susceptible to mixing by strong winds which are a characteristic climatic feature of this region. Wind generated currents are of sufficiently high velocity to maintain a sizable fraction of the silts and clays in suspension and the result is turbid water (mean light extinction coefficient $\sim 2.5 \text{ meters}^{-1}$). Accordingly, reflecting energy detected by ERTS is primarily influenced by the suspended load (the predominant fraction of which is inorganic material). The determination of the secondary influence of organic material and chemicals on reflected energy must wait until the effects of inorganic suspended load are understood. The remainder of this paper is devoted to this aspect.

3.0 GROUND TRUTH ANALYSIS

The light penetration depth is primarily controlled by suspended load. The inverse secchi depth (or 1/sunlight penetration depth) is linearly related to suspended load up to $\sim 100 \text{ ppm}$ (Figure 1). Least squares straight line fits to these data yield statistically equivalent slopes and intercepts. Although inconclusive, the few points beyond 100 ppm (not shown) indicate this linearity may hold up to 250 ppm. The greater point scatter in the Tuttle Creek data is due to higher average turbidity relative to Perry. This results in a smaller average light penetration depth and greater percent error in its measurement by the secchi disc method.

4.0 IMAGE ANALYSIS

Approximately 30 cloud-free and ice-free ERTS images of Tuttle Creek and Perry have been electronically sliced and displayed on our IDECS system. The color coded displays were recorded on 35 mm film for permanent storage and further analysis. The level slicing was done on the basis of equal vidicon output voltage intervals which is equivalent to equal log density intervals. The maximum number of levels/image was determined by the dynamic range of the particular band over the reservoir surface and varied from 2 to 8 levels. The equal gray levels selected by IDECS correspond to nearly equal reflected energy intervals as defined on the NASA 15 step

gray tablet. Maximum density variation (~ 0.6 to 1.7) is usually found on the red band (MSS5) and corresponds to a power return range of 0 to $\sim 25\%$.

5.0 COMPARISON OF IMAGERY WITH GROUNDTRUTH

Gray level contour maps of each image were prepared for comparison with suspended load and secchi measurements (example in Figure 2). In addition, the data was examined in graphical form for each reservoir pass (examples in Figures 3 and 4). The Tuttle Creek pass 2 data exhibits a strong correlation between gray level, suspended load, and secchi depth in the green (MSS4), red (MSS5) and infrared (MSS6) bands. This data is fairly representative of other Tuttle Creek and Perry passes, except in some cases the green band correlation is poor. Bands 5 and 6 normally show strong correlation with suspended load and secchi depth with band 5 being more reliable. Band 7 is poorly correlated, but usually appears somewhat brighter at the very turbid end of the reservoir. Based on the pure water spectral attenuation coefficient, best correlation would be expected in the green band. This is probably being obscured by haze induced by atmospheric scatter. Figure 5 shows band 5 correlations for the first four passes over Perry Reservoir dating from 7-27-72 to 9-19-72. This is representative of both reservoirs, in that, the dynamic range over the reservoir surface tends to shrink as winter approaches with lower sun angle and lower average turbidity.

6.0 CONCLUSIONS

Bands 5 and 6 exhibit strong correlation with suspended load and sunlight penetration depth. In some cases band 4 also exhibits strong correlation, but is not reliable and is probably quite sensitive to atmospheric conditions. Band 7 is poorly correlated, although does show a brighter return for suspended load ≥ 100 ppm. The discrimination or sensitivity between gray level and suspended load is good up to 100 ppm, but appears to rapidly deteriorate above this level of turbidity. More imagery/ground truth over high turbidity water is required for further illumination of this problem. MSS imagery obtained in the high gain mode would probably be a great help in extending the discrimination. This is feasible because the power return from the reservoir surface is never more than 30% of maximum return.

In summary, the prospects for developing a reliable low cost procedure for predicting suspended load from ERTS imagery looks very good.

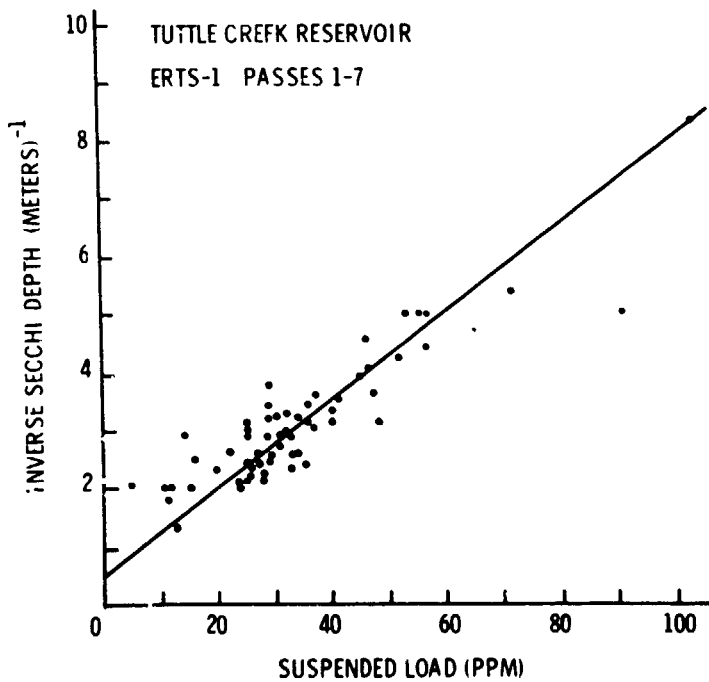
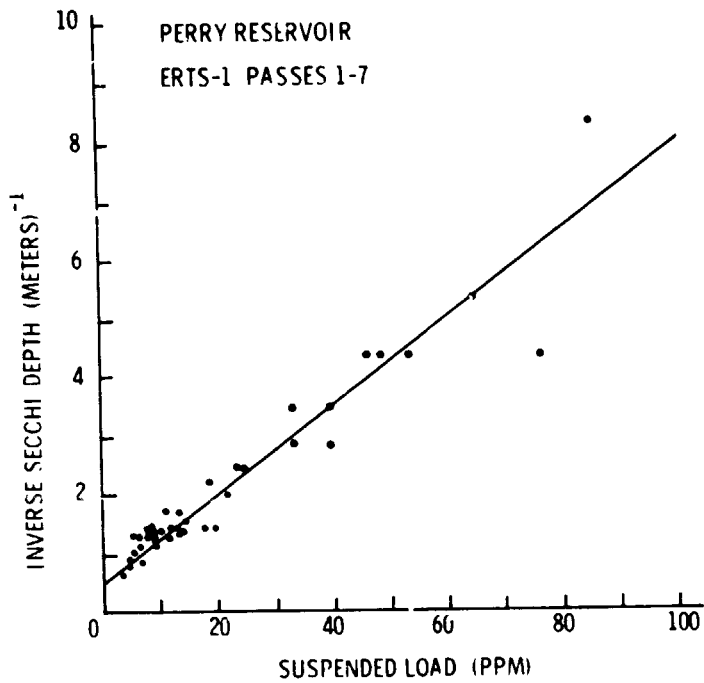


FIGURE 1. Inverse secchi depth vs. suspended load for Perry and Tuttle Creek reservoirs.

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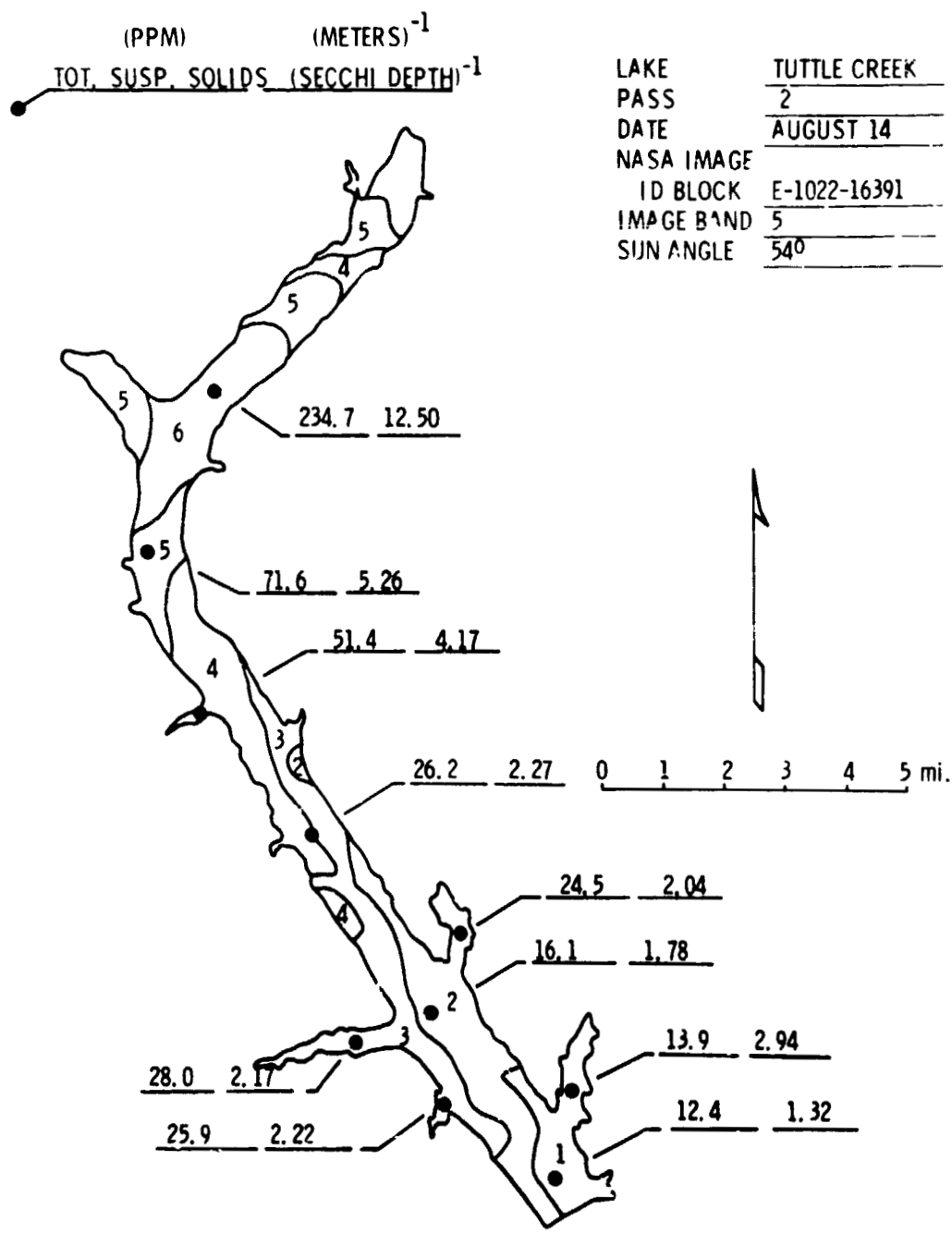


FIGURE 2. Gray level map and turbidity measurements for Tuttle Creek reservoir.

TUTTLE CREEK -- PASS 2 -- AUGUST 14, 1972

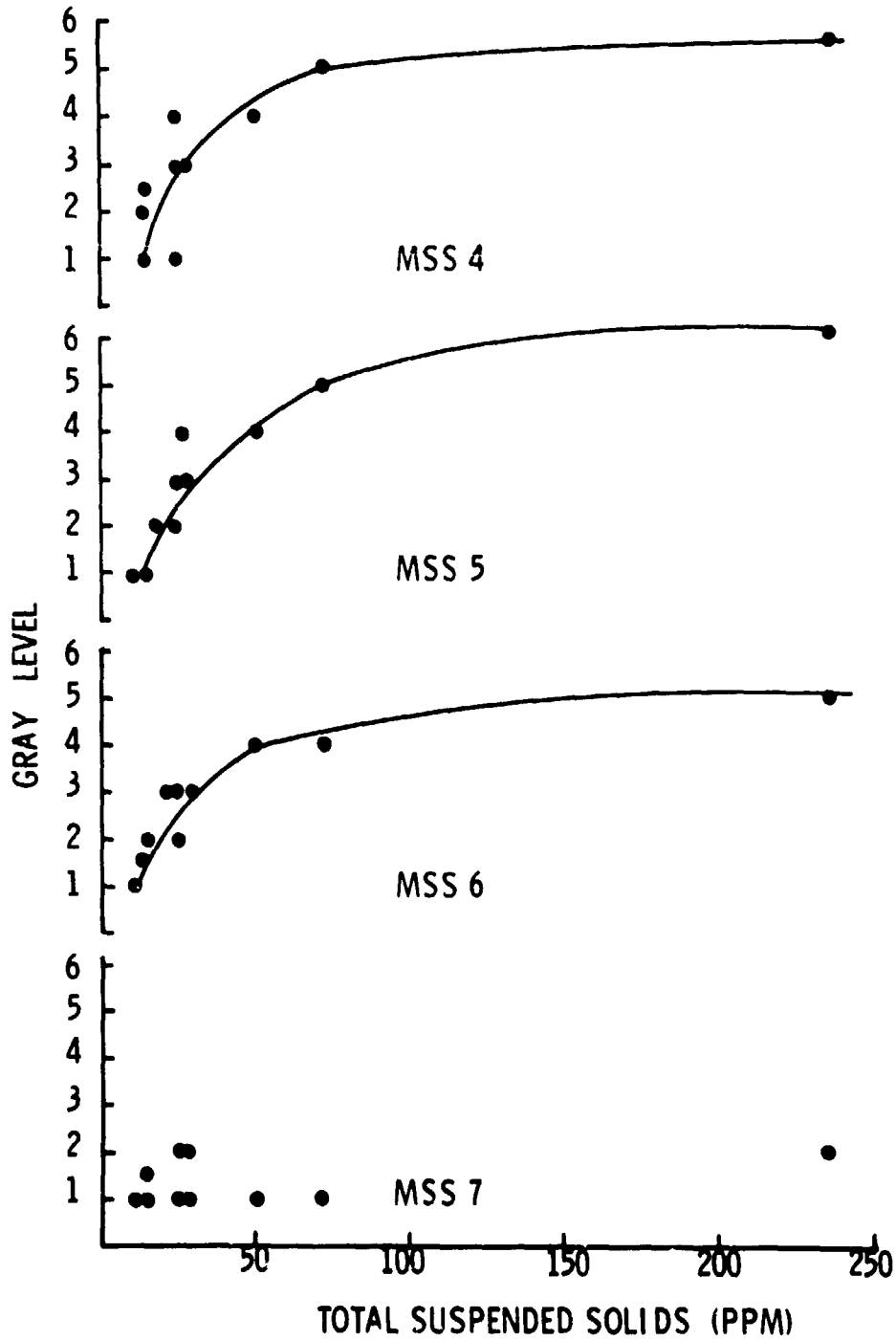


FIGURE 3. Gray level vs. suspended solids for Tuttle Creek Reservoir.

TUTTLE CREEK -- PASS 2 -- AUGUST 14, 1972

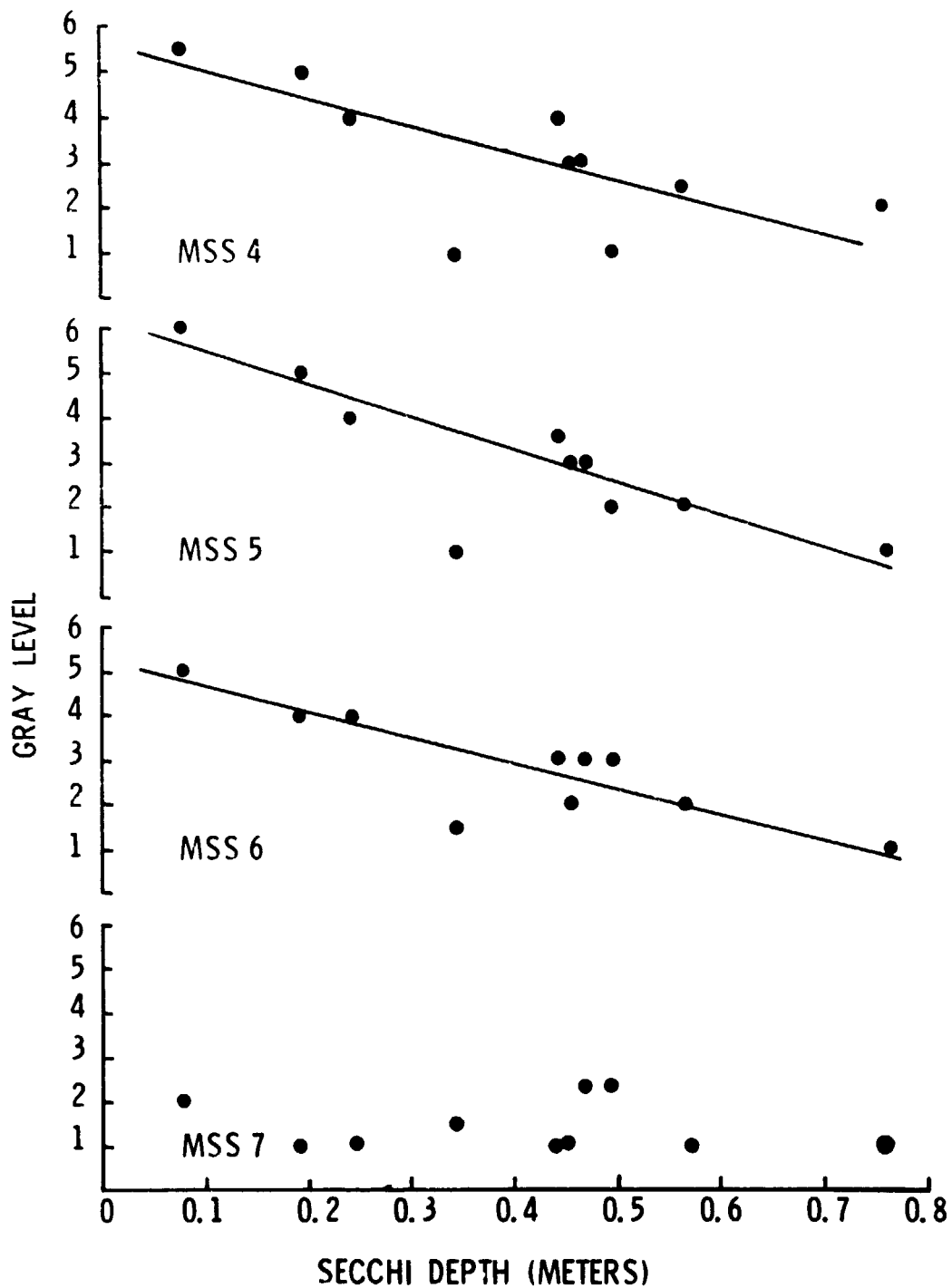


FIGURE 4. Gray level vs. secchi depth for Tuttle Creek Reservoir.

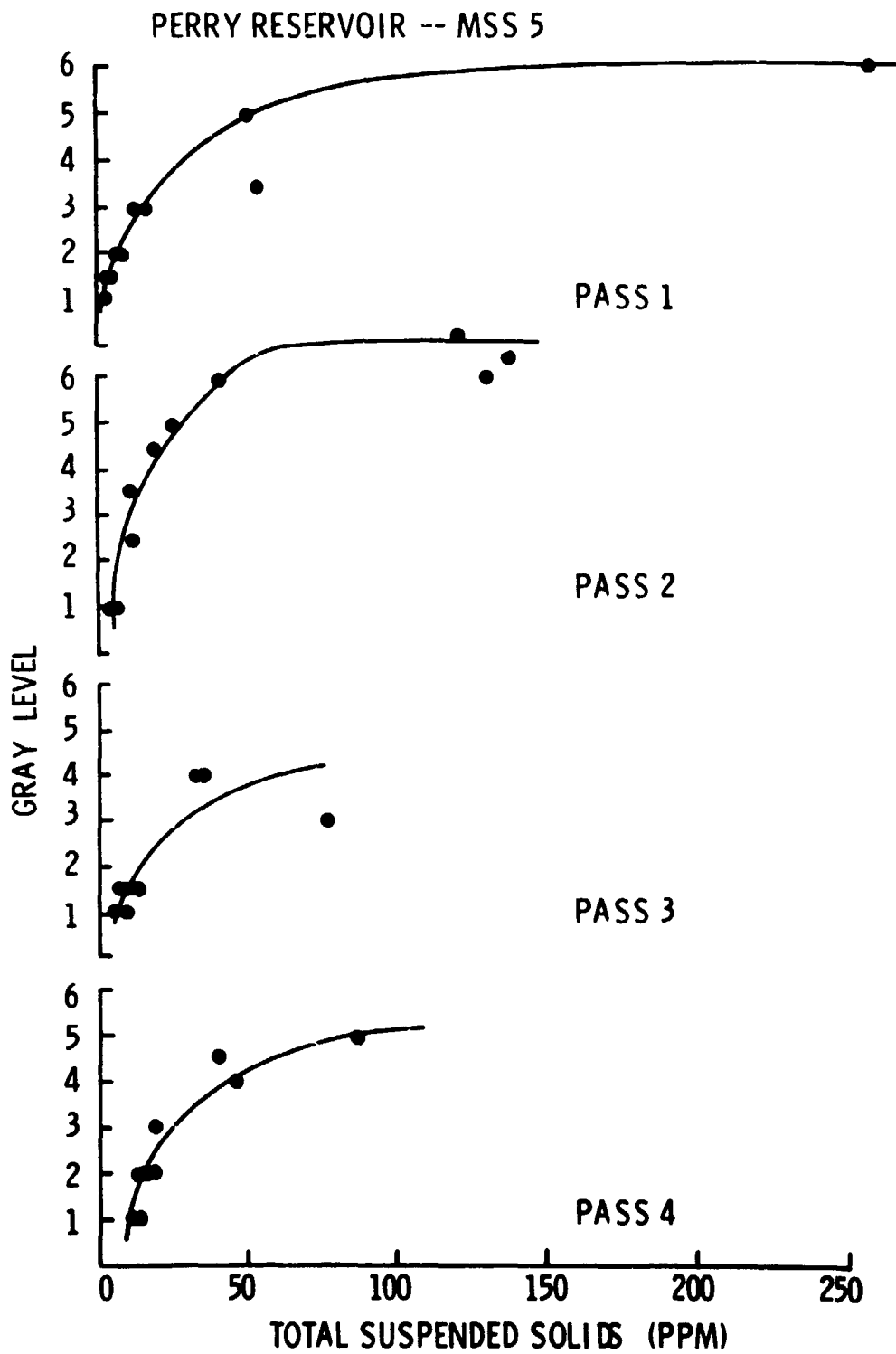


FIGURE 5. Gray level vs. suspended solids for Perry Reservoir.