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Technical Completion Report
Project No. A-039-NMEX

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New Mexico Water Resources Research Institute
*in cooperation with*
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# Abstract

Nutrient cycling studies have proven valuable in explaining the presence, abundance, and seasonal variation of elements in stream water. The long term objectives of this project are to understand mineral cycling and stream water chemistry of forested watersheds in New Mexico as influenced by vegetational communities, climatic conditions, weathering of soil minerals, and man.

Studies to date show water quality changes over elevation, with the lowest concentrations of elements occurring at the highest elevations. This trend is consistent throughout the year; however, actual concentration values vary due to the source of water (e.g. snow melt at high or low elevations) and seasonal patterns of biological activity. Variation in concentration is greatest at lower elevations. The reasons for the higher concentrations at lower elevations are increased evapotranspiration and a combination of biological controls and bedrock weathering differences. For nitrate, variation in concentration is a result, primarily, of biological activity and climatic factors (precipitation, temperature). Research needed to identify mechanisms of biological control involve transfer of materials within the system. A limited number of these results are presented. The information gathered from natural areas is essential in evaluating man's activities. The only land use activity evaluated to date has been minor:

replacing a poma ski lift on the border of a watershed. An additional loss of Ca and Mg did occur during September and October and which was attributed to the construction of the new lift. Additional ski area development is currently being evluated.

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# HYDROLOGIC NUTRIENT CYCLE INTERACTIONS IN UNDISTURBED AND MANIPULATED ECOSYSTEMS (WATERSHEDS)

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## Introduction

Research in New Hampshire indicated that a study of the interactions between nutrients and the hydrologic cycle could be used effectively in identifying nutrient cycles and other parameters of an ecosystem (Bormann and Likens,1967). Studies of nutrient cycling were especially valuable in explaining the presence, abundance, and seasonal variation of the elements in stream water. It was found that all elements do not react the same to the hydrologic cycle or to biological activity, thus indicating the complexity of reactions which occur in natural ecosystems.

A deforestation experiment resulted in significant pollution of the drainage stream from the ecosystem (Likens *et al.*, 1970; Bormann *et al.*, 1968, 1969). The treatments demonstrated how the mineral cycles of natural ecosystems are disrupted, thereby causing pollution. All of man's treatments, whether recreational or timber harvesting, are disturbances to watershed ecosystems. Consequently, we can expect disrupted mineral cycles and some degree of pollution.

The chemical reactions in New Mexico watersheds are expected to be different from those in New Hampshire because of differences in vegetation and climate. Little is currently known about mineral cycling and the functioning of natural ecosystems in the Southwest, and even less is known about how they relate to water quality. Knowledge of the basic functions of an ecosystem may establish the limits of human pressure which will allow use but not degradation of watersheds and streams.

## Objectives

The long term objectives of this study were to understand mineral cycling and stream water chemistry of watershed ecosystems as influenced by vegetational communities, climatic conditions, weathering of soil minerals, and man.

## Procedure

The Tesuque Watersheds in the Sangre de Cristo Mountains on the Santa Fe National Forest (Figure 1) were chosen because the bedrock of the area is Embudo Granite and thought to be watertight (i.e. negligible deep seepage); the area is accessible throughout the year; and the area is on federally owned land which allows controlled, long-term studies.

Eight of the watersheds are gauged and maintained by the U.S. Geological Survey (U.S.G.S.) and the U.S. Forest Service (U.S.F.S.). Eight to ten years of calibration data have been obtained. The gauged watersheds are large (116 to 415 hectares) and have a mixture of vegetation types. However, there are numerous small watersheds (10 to 25 ha) which consist of a single vegetation type (e.g. ponderosa pine). A single

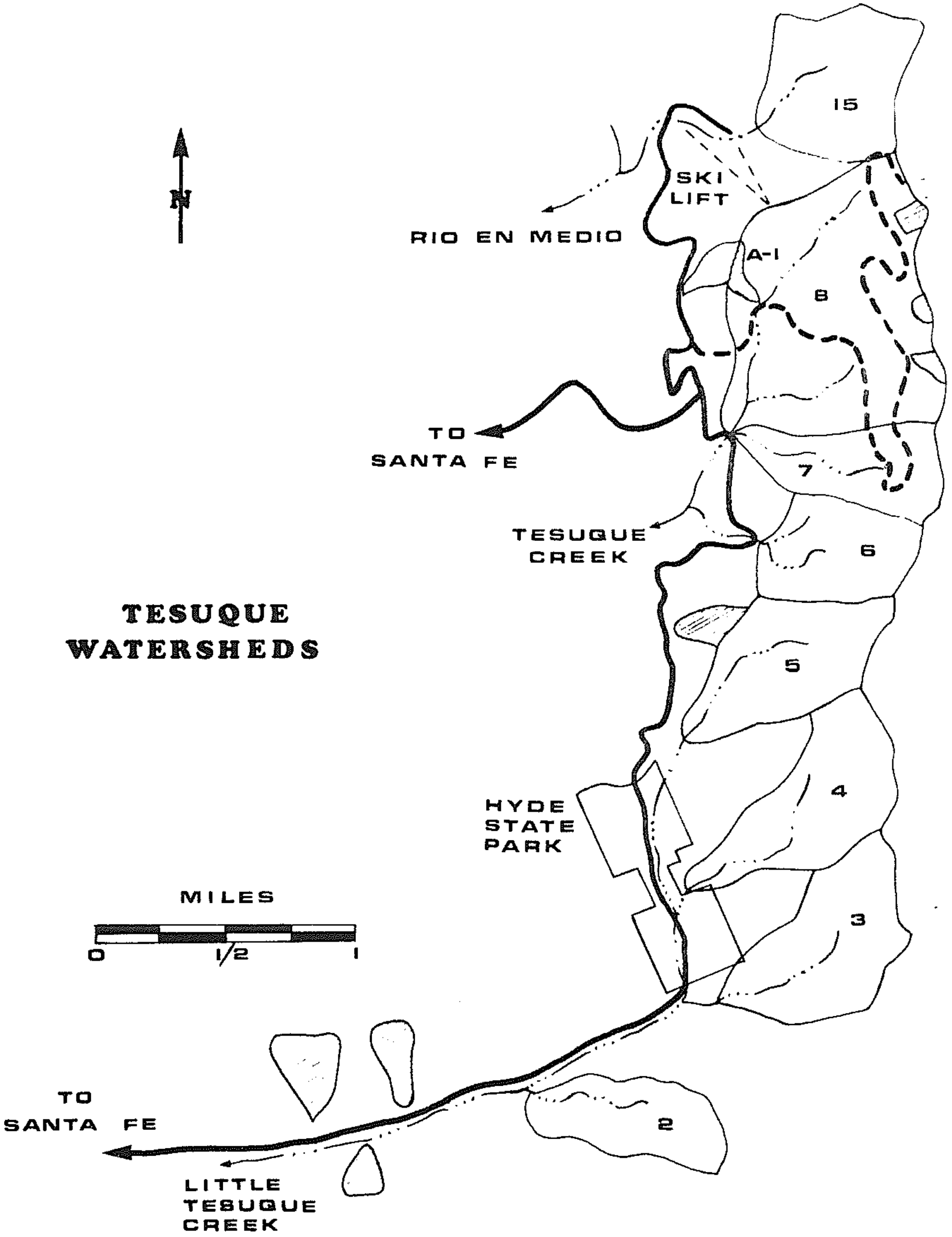

Figure 1. Tesuque Watersheds and additional small study watersheds (shaded).

vegetation type on a small watershed simplifies studies of mineral cycling: the characteristics of individual vegetation types can be compared with each other and to the large watersheds of mixed vegetation. The vegetation of the area ranges from pinon pine and juniper (at 2400 m) to alpine tundra and spruce forests (at 3734 m), (see Table 1), thus allowing study of a variety of vegetational communities and climatic variables.

In general, the procedures are concerned with periodic samplings and analysis of stream water, determination of mineral pool sizes in watersheds of different vegetational composition, and rates of transfer between mineral pools. Analyses for Ca, Mg, Na, K, and $NO_3^-$ have been made since 1971. In 1973, additional analyses were started for $HCO_3^-$, $Cl^-$, and $SO_4^=$. Precipitation volume and stream discharge data, supplied by the U.S.G.S. and the U.S.F.S., permits calculation of nutrient budgets (outputs-inputs), but up to five years of data will be required to develop predictive models of stream water chemistry and stream discharge from undisturbed watersheds. Determination of the sizes of mineral "pools" involves estimates of plant and animal biomass and analyses of minerals in different tissues of the various species. The pools to be studied are: standing plant biomass; animal biomass; organic debris; soil; and bedrock. Subsequent studies of soil weathering, mineral uptake, leaf wash, litter fall, animal consumption and egestion, and decomposition will ascertain rates of transfer between the mineral pools (mineral cycling).

Table 1. Characteristics of the Tesuque Watersheds; discharge, elevations, vegetation.

| Item | Watershed number | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 15 |
| Runoff (cm) | | | | | | | | |
| 1963[a] | 1.12 | -- | -- | 8.89 | 16.05 | 21.06 | 28.78 | -- |
| 1964[a] | 0.76 | 1.83 | -- | 7.21 | 14.78 | 19.05 | 26.95 | 39.78 |
| 1965[a] | 0.89 | 1.90 | 7.75 | 14.38 | 27.28 | 36.80 | 46.46 | 65.93 |
| 1966[a] | 1.12 | 2.46 | 6.71 | 13.34 | 26.67 | 34.01 | 42.60 | 47.96 |
| 1967[a] | 0.23 | 0.38 | 1.70 | 4.37 | 10.06 | 11.63 | 17.58 | 28.07 |
| 1968[a] | 0.64 | 2.31 | 7.52 | 10.41 | 20.17 | 27.81 | 36.04 | 44.40 |
| Average (cm) | 0.79 | 1.78 | 5.92 | 9.78 | 19.18 | 25.07 | 33.07 | 45.24 |
| Elevation (m) | | | | | | | | |
| Maximum | 2850 | 3109 | 3383 | 3444 | 3520 | 3490 | 3658 | 3734 |
| Minimum | 2423 | 2576 | 2621 | 2804 | 2972 | 2987 | 2941 | 3231 |
| Vegetation (ha) | | | | | | | | |
| Pinon-Juniper | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pine | 106 | 62 | 0 | 11 | 0 | 0 | 0 | 0 |
| Mixed Conifer | 0 | 107 | 100 | 18 | 0 | 0 | 0 | 0 |
| Spruce-Fir | 0 | 0 | 80 | 112 | 103 | 64 | 45 | 123 |
| Aspen | 0 | 0 | 0 | 23 | 19 | 13 | 203 | 0 |
| Non-timbered | 0 | 0 | 0 | 0 | 0 | 23 | 166 | 40 |
| Total (ha) | 166 | 169 | 180 | 164 | 122 | 100 | 415 | 163 |

[a] water year

One additional weir has been installed on a small aspen watershed with the assistance of the U.S.G.S. Weekly stream samples were collected for analysis. During periods of high discharge, more frequent sampling occurred. An attempt to install a second weir on a small spruce-fir watershed failed because of improper substrate conditions. A search for an alternate site is in progress.

Five fenced weather stations were established at 8,500, 9,200, 10,200, 11,200, and 11,800 feet elevation. Each has a standard storage precipitation gauge. The stations at 9,200, 10,200, and 11,200 feet also have polyethylene precipitation collectors and recording precipitation gauges. Weekly chemical analyses were made on precipitation from the polyethylene collectors. The U.S.F.S. has weather stations at 8,000, 9,800, and 10,600 feet elevation which have storage precipitation gages, recording precipitation gauges, and hygrothermographs. Hourly precipitation, air temperature, and humidity is prepared by C. Keyes, Weather Modification Research Program. Four multiple pen recording thermographs were set up to record soil and water temperatures on several watersheds. A recording pyranograph was set up to record incident radiation.

To survey vegetation on watersheds of a single vegetation type (aspen, spruce-fir, spruce, and pinon pine-juniper watersheds), a base line was surveyed up the center of each watershed and marked off at 25m intervals. At each 25m mark, perpendicular lines were run off and marked at 25m intervals. Each square in this 25m x 25m grid had an identifying row and column number for reference.

Species and diameter of all trees > 2cm were recorded on a 10m x 10m plot placed randomly in each square of the grid system. This constituted a 16 percent sample of the entire area and allowed estimation of the mean basal area within ±10% (Bormann, 1963). Tree samplings < 2cm dia. and > 0.5m high were recorded on four 2.5m x 2.5m quadrants in each of the corners of the $100m^2$ plot. Three seedlings < 0.5m high were counted on four 1m x 1m quadrants similarly positioned in the $100m^2$ plot.

Decomposition studies of slowly decaying material (tree stems) were initiated. Aspen, cork-bark fir, engelmann spruce, white fir, and douglas fir which had a diameter breast high of 7± 0.1 inches (17.5 ± 0.2cm) and minimum bole taper were studied. Three trees of each species were felled, cut into sections, and 5-cm thick disks were taken systematically along each stem. These disks were analyzed for moisture content, percent wood and bark, and nutrient content. These data will be used as baselines for subsequent analyses of stem decomposition.

Ten permanent litter traps (each $4m^2$) were established randomly on the aspen, englemann spruce, and spruce-fir watersheds to allow yearly comparisons of small branch litter fall for each community. The contents of these traps were collected yearly.

Throughfall is being measured on the aspen watershed by a number of standard 8" rain gauges. Polythylene collectors are being used to collect throughfall for chemical analysis.

## Results and Discussion

### Water Chemistry:

The research involved natural levels of nutrients in stream water from a number of gauged watersheds near Santa Fe, New Mexico, having different vegetational communities. This range of communities also represents a range of environmental factors (i.e. temperature, precipitation, humidity, etc.). The bedrock of all watersheds is Embudo Granite.

Water quality differs in each of the watersheds as shown in Tables 2 and 3. The differences between values for the two tables are partly explained by the fact that Table 3 results are for the entire year (including spring discharge). Concentrations tend to increase as elevations decrease. This trend is very consistent in these watersheds throughout the year. Analyses of stream water taken over the entire length of the Santa Fe River in the Santa Fe Municipal Watershed confirm patterns found in the Tesuque Watersheds (Figure 2). The Santa Fe Watershed borders the Tesuque Watersheds and has the same bedrock. Nutrient concentrations in the main stream increased progressively as the stream dropped in elevation. This was the result of higher concentrations of nutrients in feeder streams at lower elevations. The pattern remained the same seasonally; however, the magnitude of the numbers in the

Table 2. Weighted average concentrations for the Tesuque Watersheds during June-December, 1971. (W-15 is the highest gauged watershed; W-2 is the lowest gauged watershed.)

| | Weighted Concentration (ppm) | | | | |
|---|---|---|---|---|---|
| Watershed | Ca | Mg | Na | K | $NO_3$ |
| W-15 | 2.86 | 0.47 | 1.96 | 0.53 | 0.22 |
| W-8 | 2.78 | 0.72 | 2.22 | 0.71 | 0.12 |
| W-7 | 3.46 | 1.11 | 2.30 | 1.02 | 0.31 |
| W-6 | 3.16 | 1.10 | 2.62 | 0.66 | 0.18 |
| W-5 | 4.28 | 1.58 | 3.36 | 1.08 | 0.54 |
| W-4 | 6.49 | 2.92 | 5.00 | 1.28 | 1.16 |
| W-2 | 27.80 | 12.12 | 11.06 | 1.08 | 0.88 |

Table 3. Weighted yearly average concentrations for the Tesuque Watersheds during 1972. (W-15 is the highest elevation watershed; W-2 is the lowest gauged watershed. The Pinon-Juniper (P-J) weighted averages were estimated using W-2 discharge data.)

| | Weighted Yearly Average Concentrations (ppm) | | | | |
|---|---|---|---|---|---|
| Watershed | Ca | Mg | Na | K | $NO_3$ |
| W-15 | 3.59 | 0.68 | 2.23 | 0.55 | 0.25 |
| W-8 | 3.37 | 0.87 | 2.43 | 0.71 | 0.13 |
| W-7 | 3.94 | 1.13 | 2.48 | 1.02 | 0.24 |
| W-6 | 4.51 | 1.26 | 2.83 | 0.69 | 0.18 |
| W-5 | 4.95 | 1.67 | 3.52 | 1.16 | 0.49 |
| W-4 | 6.75 | 2.59 | 4.77 | 1.28 | 1.24 |
| W-2 | 41.52 | 11.35 | 11.25 | 1.14 | 0.67 |
| P-J | 91.97 | 35.73 | 17.64 | 2.43 | 0.75 |

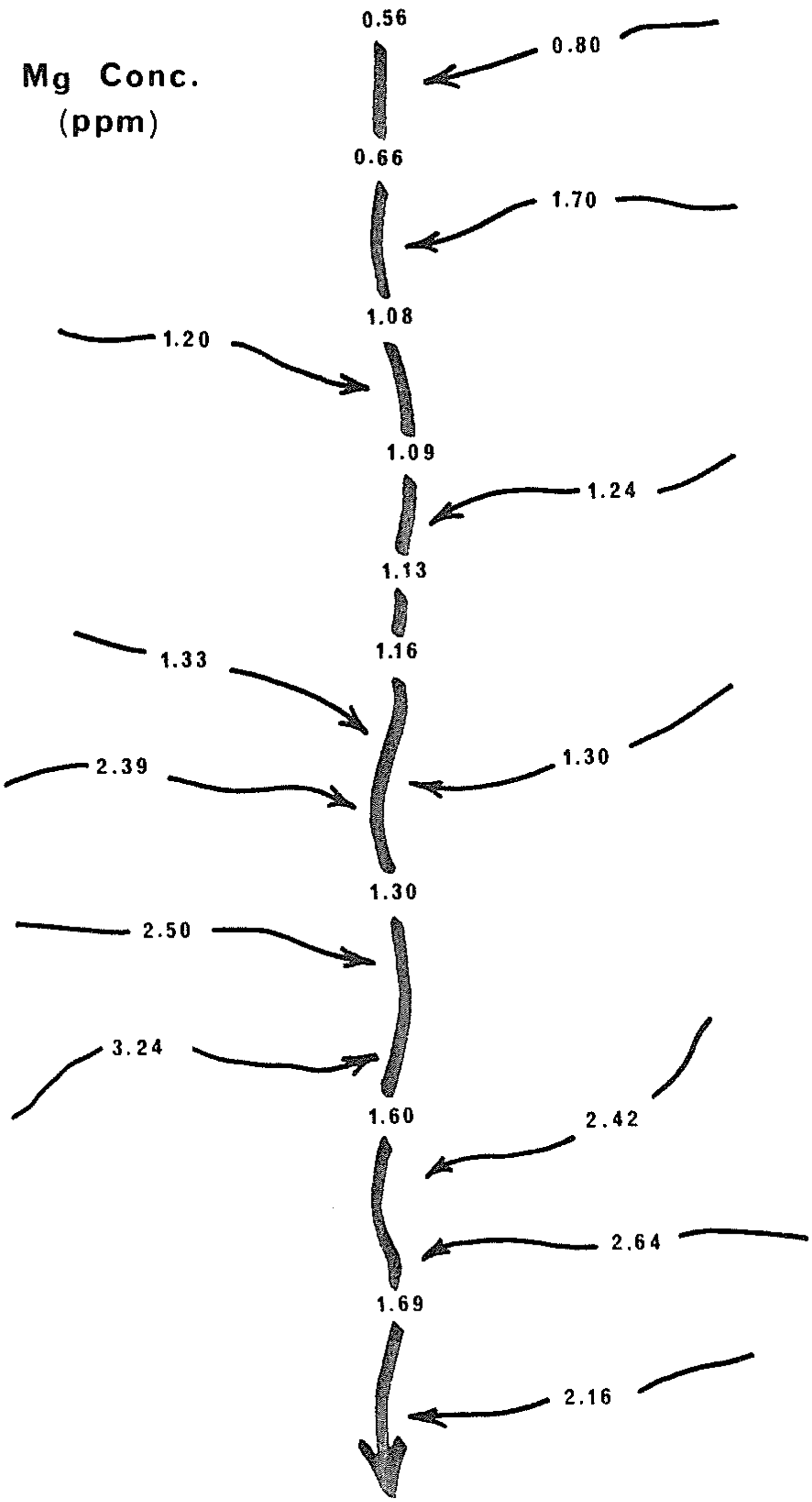

Figure 2. Magnesium concentrations (ppm) in the main stream and feeder streams in the Santa Fe Municipal watershed.

main stream changed. Early in the spring the majority of snow melt occurred at the low elevations and element concentrations in stream water were relatively high at the base of the watershed. Later in the spring the discharge was a result of snow melt at high elevations and element concentrations throughout the main stream were relatively low. This may be of practical importance since cutting timber at upper elevations to increase water yield increases the rate of snow melt. Thus, more water from upper elevations may dilute element concentrations normally found in early spring. The effects of timber cutting may change this pattern, however (Likens _et al_., 1970).

In addition to an increase in concentration, variability also increases with a decrease in elevation (Table 4). Several reasons may account for the increased concentrations. Increased evapo-transpiration (concentration) can account for these increases down to watershed 2 for Ca, Na, and K. Evapotranspiration ranged from 63% on W-15 to 98% on the P-J watershed during 1972. In fact, evapotranspiration could cause concentrations greater than those found. This suggests that there is some control related to biological factors (a dampening effect) exerted by the ecosystem. However, evapotranspiration cannot explain the high concentration of Mg in W-2 nor the high Ca, Mg, and Na concentrations in the P-J watershed. Currently, detailed bedrock analyses are being made to identify any differences in mineral composition.

Table 4. Mean concentration (ppm) and standard error of nutrients in weekly stream water collections during the period June-December, 1971.

| Watershed | Calcium | Magnesium | Sodium | Potassium | Nitrate |
|---|---|---|---|---|---|
| #15 | 2.93 (0.04) | 0.49 (0.05) | 1.94 (0.06) | 0.54 (0.02) | 0.21 (0.02) |
| # 8 | 2.84 (0.04) | 0.71 (0.05) | 2.27 (0.03) | 0.74 (0.02) | 0.11 (0.01) |
| # 7 | 3.48 (0.04) | 1.09 (0.06) | 2.33 (0.03) | 1.01 (0.02) | 0.25 (0.03) |
| # 6 | 3.19 (0.04) | 1.06 (0.04) | 2.65 (0.03) | 0.67 (0.01) | 0.15 (0.02) |
| # 5 | 4.59 (0.18) | 1.71 (0.04) | 3.48 (0.06) | 1.14 (0.02) | 0.62 (0.04) |
| # 4 | 7.67 (0.51) | 3.46 (0.15) | 5.28 (0.13) | 1.29 (0.04) | 1.09 (0.18) |
| # 3 | 7.40 (1.00) | 4.60 (0.40) | 5.63 (0.37) | 0.84 (0.65) | 0.60 (0.09) |
| # 2 | 24.63 (3.08) | 11.20 (0.90) | 10.45 (0.36) | 1.21 (0.60) | 0.91 (0.82) |
| Spruce-fir | 3.70 (0.04) | 1.32 (0.03) | 1.70 (0.02) | 1.12 (0.01) | 0.21 (0.02) |
| Aspen | 3.86 (0.07) | 0.88 (0.05) | 3.20 (0.03) | 0.74 (0.03) | 0.22 (0.02) |
| Pinon-juniper | 62.76 (4.76) | 33.04 (2.11) | 14.55 (1.04) | 2.21 (0.13) | 0.88 (0.13) |

Some preliminary conclusions show the rocks of the study area, although mapped as the Embudo granite, range in composition from amphibolite to granite. About eight groups have been field classified. Two of these are meta-volcanics or meta-sediments and are high in ferromagnesian minerals and calcic plagioclase and lacking in quartz. Pyrite is occasionally visible in these rocks. The remainder of the rocks appear to form an intrusive series following a calk-alkaline trend. Quartz becomes increasingly abundant in the later intrusions, as does potassium feldspar. Biotite is the principal mafic mineral and varies from about 50 to 3 percent of this series. The separate lithologies of the intrusive series are unmappable in the usual geologic sense because the scale of the separate bodies is too small and outcrops form generally less than 5% of the area of the watershed basins.

In general the lower basins are nearer the margins of the intrusion and contain a larger amount, perhaps up to 50%, of mafic metamorphic rocks. In the upper basins amphibolite appears to compose less than 2% of the bedrock. It appears that the best method for estimating the chemical composition of the bedrock in a given basin is to sample pebbles in as many locations in the streams as feasible. This is in progress.

Discharge has been shown to affect concentrations of elements in stream water as well as total losses of elements from the watershed. Figures 3 and 4 show gross outputs of

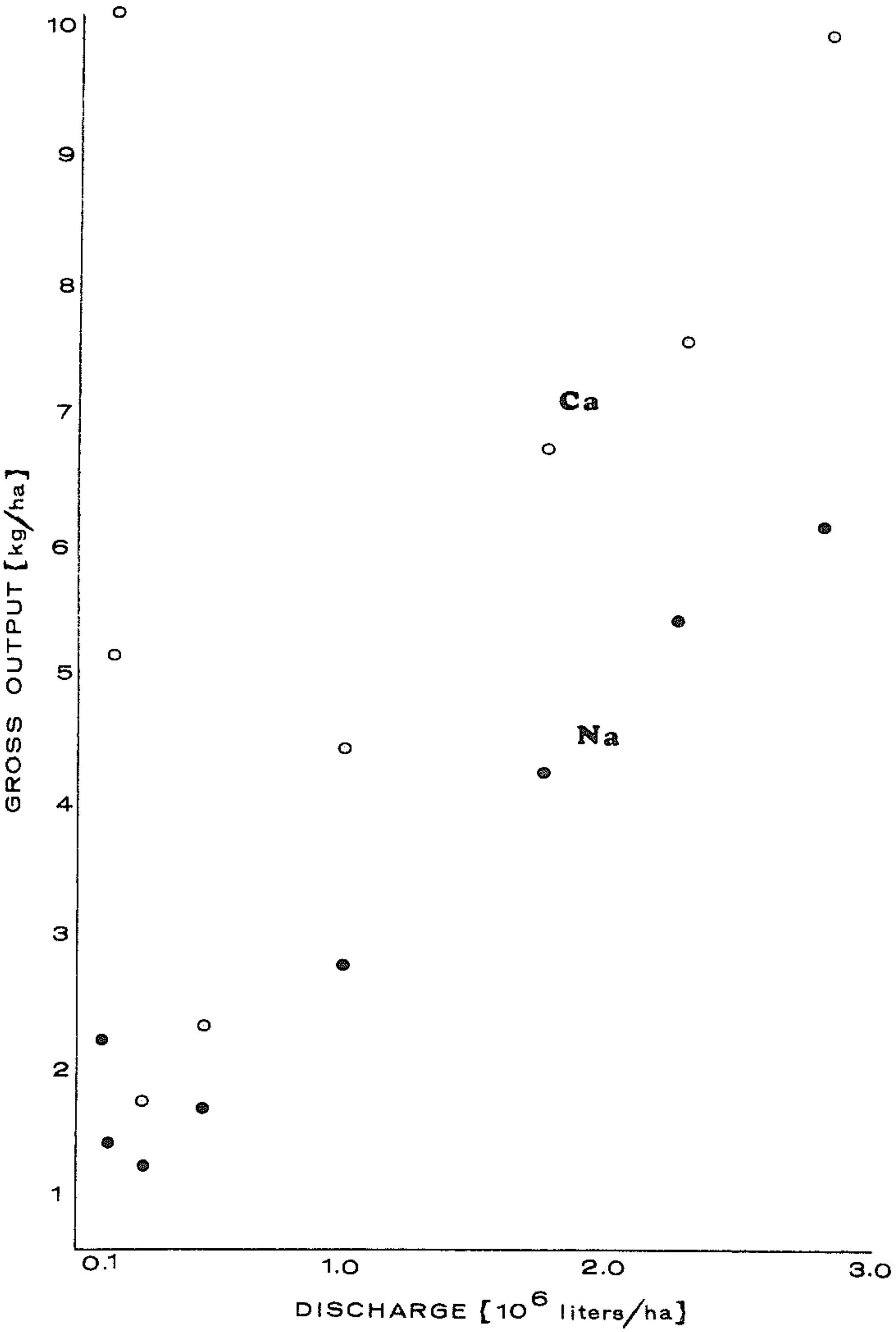

Figure 3. The relationship between discharge and gross output of Ca and Na for the Tesuque Watersheds during 1972.

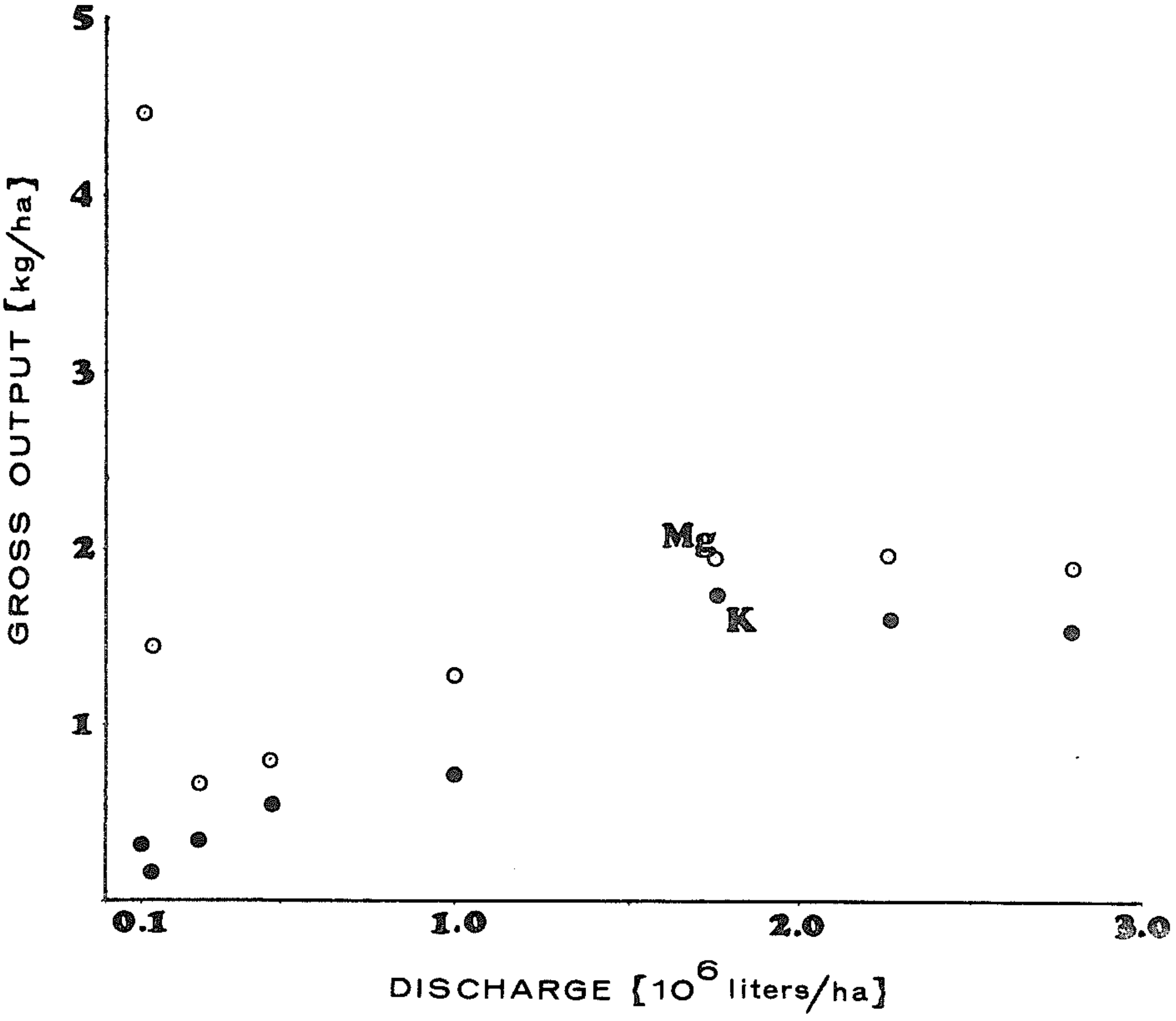

Figure 4. The relationship between discharge and gross output of Mg and K for the Tesuque Watersheds during 1972.

cations in relation to total discharge for the eight watersheds during 1972. The relative positions of these elements agree well with output-discharge studies in New Hampshire (Likens and Bormann, 1972). Watershed 15 has the highest discharge, P-J the lowest. For Ca and Na there is a linear relationship down to W-4. Watershed 2 and the P-J watershed break the relationship, showing excessive losses in spite of very low discharges. For Mg and K, the P-J watershed again seems to lose control causing excessive losses. The upper watersheds (7,8,15) also break the linear trend suggesting a dampening effect or control exerted by the ecosystem. This relationship also can be seen in Table 5: cation flux (output-input) for 1972. Analysis of precipitation chemistry over the elevational range during the 1971-72 period shows only small differences in annual input. This is a result of low concentrations and high annual precipitation at the higher elevations: higher concentrations and lower annual precipitation at low elevations. This explains the similarity between net and gross output.

| | | |
|---|---|---|
| Precipitation inputs | Ca | 1.12 - 1.50 kg/ha-yr |
| | Mg | 0.06 - 0.09 kg/ha-yr |
| | Na | 0.24 - 0.31 kg/ha-yr |
| | K | 0.09 - 0.21 kg/ha-yr |
| | $NO_3$ | 0.23 - 0.42 kg/ha-yr |

These results are lower than those reported in the 1972 progress report which were based on 6 months data.

Although discharge affects concentrations, correlations between concentration and instantaneous discharge over the entire year generally were non-significant or negative for all cations.

Table 5. Cation flux (output in streamflow minus input in precipitation) for 1972.

| | 1972 Cation Flux (kg/ha) | | | |
|---|---|---|---|---|
| Watershed | Ca | Mg | Na | K |
| W-15 | 8.92 | 1.82 | 6.01 | 1.34 |
| W-8 | 6.51 | 1.88 | 5.26 | 1.39 |
| W-7 | 5.70 | 1.87 | 4.05 | 1.56 |
| W-6 | 3.38 | 1.17 | 2.58 | 0.48 |
| W-5 | 0.87 | 0.74 | 1.37 | 0.46 |
| W-4 | 0.26 | 0.61 | 0.93 | 0.24 |
| W-2 | 3.70 | 1.35 | 1.10 | 0.05 |
| P-J | 10.02 | 4.41 | 1.90 | 0.21 |

This is a result of the large size and mixture of communities on most of the watersheds. Precipitation is greater at the highest elevations of a watershed. Since cation concentrations are low in stream water at high elevations, the relatively large volume of good quality water from the upper portions of a watershed dilutes concentrations normally found at the lower elevations causing negative correlations. Correlations of concentration and discharge on small watersheds (e.g. a small pure aspen watershed recently gauged) show a negative correlation for Na but a significant positive correlation for K. Potassium concentrations are affected by time of year also. Concentrations tend to be higher during winter months and lower during summer months, suggesting biological regulation. This agrees well with data from watersheds in New Hampshire and North Carolina.

Calcium concentrations are not correlated with discharge for the entire year, but the relationship also seems affected by time of year. During months with snow cover the correlation is non-significant. During snow-free months a significant negative correlation exists. This may be the result of a difference in precipitation form as well as temperature.

Tables 2, 3, 4, and 5 also show a changing relationship between Mg and Na over elevation, a natural softening effect. On the higher watersheds Na exceeds Mg, but the relationship gradually changes until at lower watersheds Mg exceeds Na. This relationship also can be seen in the water analysis diagram (Fig. 5). In the lower left triangle for cations,

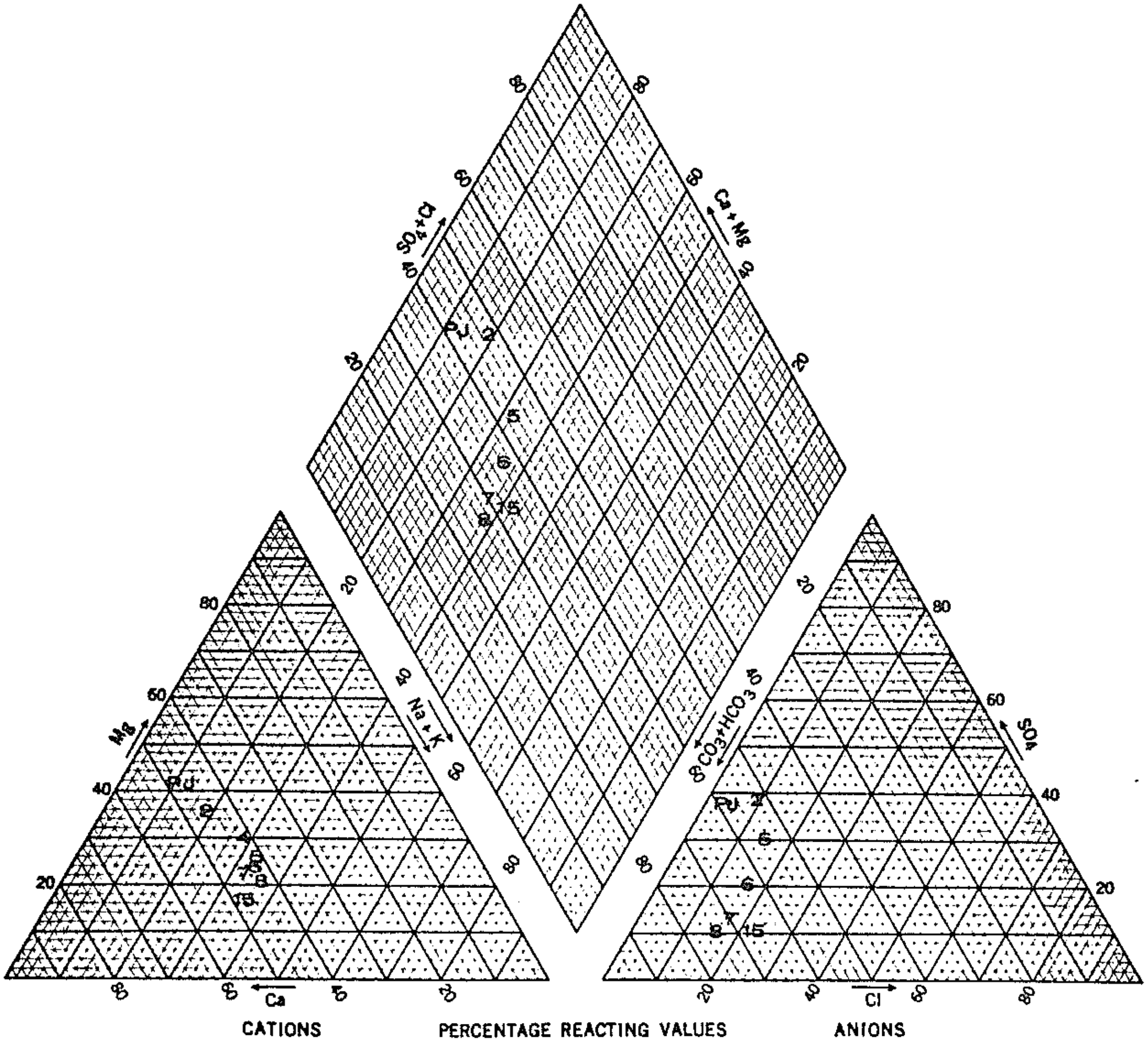

Figure 5. Water analysis diagram demonstrating the change in the relative importance of various cations and anions over elevation.

there is a shift in the importance values of Mg and Na with a change in watersheds. Anions also show a corresponding shift with the major changes between $HCO_3^-$ and $SO_4^=$. Streams seem to change from a relatively high Na and $HCO_3^-$ system at high elevations to a relatively high Mg and $SO_4^=$ system at low elevations.

The patterns described above are thought to be a combination of biological and physical factors. Rates of decomposition, organic matter accumulation, uptake by vegetation, and physical weathering of bedrock minerals all may be involved. Our current research attempts are designed to evaluate the importance of each.

Nitrate ion is of particular importance because of its biological importance and its relation to discharge. On the small aspen watershed (small area - single vegetation type), $NO_3^-$ concentrations are significantly and positively correlated with discharge. On watersheds 2 and 4 this relationship also holds. The higher watersheds have the relationship modified. Watershed 5 shows a positive correlation for the entire year; however, the relationship is not significant during May through August. Watersheds 7 through 15 show non-significant correlations during the year. These patterns appear to be the result of complex relationships between amount, type, and frequency of precipitation as well as temperature and biological activity. In watershed 7, for example, during the snow-covered months, $NO_3^-$ concentrations seem to be a function of discharge (temperature regulated); however, the values are at a somewhat higher level than during snow-free months. This has been reported previously as a result of decreased biological activity (uptake by vegetation, Johnson *et al.*, 1969). The quantity of $NO_3^-$ leaving during snow melt can be accounted for entirely by $NO_3^-$ concentrations in snowfall. During the snow-free months $NO_3^-$ concentrations are not related to discharge; however, they are significantly affected by quantity of precipitation. The multiple correlation coefficient for $NO_3^-$ concentration with precipitation during the previous 24 hours and precipitation during the previous 48 hours is 0.92. This explains 85% of the variance. The F value for a multiple regression analysis of these variables is 62.43 (D.F. = 2,22).

Concentrations also seem to be affected by intervals between rains. A heavy rain can cause a high discharge and a high $NO_3^-$ concentration in the stream water. Soon after, discharge returns to normal but the $NO_3^-$ concentration remains relatively high, a lag effect. The significant regression analysis suggests this lag effect lasts at least 2 days. If another heavy rain occurs soon, discharge again goes up; however, $NO_3^-$ concentrations do not go up quite as high as they did previously. If there is more time between heavy rains (1-2 weeks), then $NO_3^-$ concentrations will go relatively high each time. It appears as though there is a production of $NO_3^-$ (nitrification) which accumulates between rains. The longer the interval between rains, the more that will have accumulated and the more that will be flushed out. This is especially pronounced in the lower watersheds having relatively little vegetational cover and presumably less uptake of $NO_3^-$. At higher elevations the vegetation appears to prevent the accumulation of a large pool of $NO_3^-$., and while precipitation causes a flush of $NO_3^-$ into the stream, concentrations are much lower.

Research is being initiated to evaluate the nature of the lag effect in $NO_3^-$ concentrations in stream water and the rate of $NO_3^-$ produced in different vegetation types during the summer season.

The evidence to date suggests biological control over water quality may be important. Research needed to identify mechanisms responsible must involve transfer of materials within the system (intrasystem nutrient cycling, Gosz et al., 1972, 1973, 1974). A number of studies are now in progress, but, only a few results are available at this time.

Vegetation Analysis:

Four watersheds have had a quantitative vegetation analysis performed. Table 6 shows density and basal area for 3 communities. Data from the englemann spruce analysis is not yet available. Information from these analyses will be used to estimate total vegetation biomass and nutrient content of each watershed.

Data from seedling analyses as well as age and growth rate measurements are in the computer analysis stage. A species check list and a field key for the understory plants are being prepared.

Table 6. Vegetational analysis of the tree species on the spruce-fir, aspen, and pinon-juniper watersheds of the Tesuque study area.

| Area & Species | Number of trees per hectare | Basal area sq. ft. per hectare | Total abundance percent |
|---|---|---|---|
| SPRUCE-FIR | | | |
| *Picca englemanni* | 1,675.4 | 762.7 | 73.9 |
| *Abies lasiocarpa* var. *arizonica* | 592.0 | 174.8 | 26.1 |
| ASPEN | | | |
| *Populus remuloides* | 3,080.0 | 414.1 | 99+ |
| PINON-JUNIPER | | | |
| *Pinns edulis* | 1,347.8 | 122.7 | 97.3 |
| *Juniperus monosperma* | 37.8 | .29 | 2.7 |

## Litterfall:

Results for branch litterfall are available for the spruce ( 86 kg/ha-yr) and aspen ( 90 kg/ha-yr) watersheds. The two vegetation types did not differ significantly ($p < .05$) in amount of branch litter, nor was year to year variation significantly different. Aspen leaf fall is currently being measured. Chemical analysis of litter material will allow evaluation of element return to the forest floor via one route.

## Throughfall:

An intensive throughfall study was started during the summer of 1973 in the aspen watershed. Results to date show the quantity of throughfall is 70% of precipitation in the open. During the month of July, for example (8.9 cm of precipitation), the amount of Ca, Mg, Na, and K leached from the leaf canopy was 1.6, 0.5, 0.0, and 10.7 kg/ha, respectively. Potassium is leached quite readily from leaf tissue, especially mature or senescent leaves. This compares well with throughfall data from other deciduous forests (Eaton *et al.*, 1973). Data of this nature will quantify element return to the forest floor via a second route. This data also helps to explain some of the variation in K concentrations in stream water. Potassium characteristically shows a peak in concentration during the autumn. This appears to be the result of significant leaching of K from senescent aspen leaves while the vegetational uptake is relatively low. The excess K can then enter the stream (Likens *et al.*, 1967).

## Faunal Studies:

Currently, a quantitative bird study is in progress on the pinon-juniper, aspen, and spruce-fir watersheds. Eighteen species of birds have been identified as inhabitants on both the spruce-fir and aspen watersheds, while 27 species have been identified on the pinon-juniper watershed. The number of individuals/ha is being ascertained. This data will allow an estimate of energy use and nutrient movement by this segment of the fauna for these watersheds.

## Management Activities:

The data gathered to date is very valuable in identifying natural variations in streamwater draining different vegetation communities over time. This baseline information is critical in assessing any disturbance as a result of man's activities. Baseline information will continue to be collected to more accurately model natural water chemistry. This is especially important on the lower watersheds which are more variable in nature. It is estimated that 5 years' data will be required. The upper elevation watersheds have a more consistent water chemistry, and evaluation can be made of management effects on these watersheds at the present.

A number of land management practices have been planned, Although to date the only one applied has been very minor: replacing a poma ski lift along the south boundary of watershed 15. The construction period was during September and October of 1972, and the major impact was that of constructing new concrete piers for the towers. Using the stream chemistry of W-15 for 1971, as well as 1971 and 1972 data from adjacent watersheds, we are able to identify an additional net loss of Ca and Mg from the watershed as a result of the construction. The additional Ca loss amounted to 25% of the total Ca lost during the year. The additional Mg loss was 3% of the total Mg lost during the year. It is suspected that the concrete (during the pouring stage) was the source of the additional Ca and Mg losses.

Currently a new poma lift is being constructed in an untimbered area near the stream in W-15. This represents a more severe manipulation which is now under evaluation. Next year timber cutting will begin in order to open additional ski runs. This represents a still more severe treatment. Through this progressive application of treatments, hopefully, any limit in the tolerance of the ecosystem to manipulation (in this case ski area development) will be identified.

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