# ASSESSMENT OF CURRENT

# OCCOQUAN WATER SUPPLY SITUATION

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## Introduction

In late August, the Interstate Commission on the Potomac River Basin (ICPRB) staff participated in an historical analysis of the dependability of yield from the Occoquan Reservoir. At that time, mandatory restrictions on water use in the Fairfax County Water Authority (FCWA) service area were being considered. The results of this historical analysis were compared to the summer of 1977 withdrawals from the Occoquan Reservoir. The comparison lead the ICPRB to work with the U. S. Geological Survey (USGS) to quantitatively analyze the risks involved. It quickly became evident that the risks of severe water shortage were much greater than either the ICPRB or USGS staffs had originally supposed.

FCWA was immediately contacted and shown the preliminary results. At the request of FCWA, USGS and ICPRB staffs refined the analysis, confirming that a substantial risk existed for depleting the existing water supply.

To resolve any questions as to the effect of extremely low groundwater levels on the analysis, the ICPRB staff contacted the Hydrologic Research Laboratory of the National Weather Service (NWS) to independently analyze the risk situation. At the further request of FCWA, NWS agreed to calibrate its groundwater based streamflow generation model on the Occoquan and to use it to assess risk from historical meteorological data. The NWS effort fully corroborated the results of the previous analysis.

Since mid-September, an ad-hoc working group composed of representatives from Fairfax County, Prince William County, the City of Alexandria, FCWA, USGS, NWS, and ICPRB, and organized by FCWA, has been actively involved in the study. Three meetings of the ad-hoc working group have been held.

This report: 1) outlines the techniques used in the analyses; 2) describes the current reservoir storage and groundwater situation; 3) presents the results of the risk analysis; 4) quantifies the effects of reductions in the current withdrawal rate on the risks; and 5) recommends a prudent approach to balancing the risk and inconvenience to FCWA customers.

This report cannot predict what will happen in the current drought situation. It does, however, examine all those things which could happen and quantifies the chances that any of those things will actually occur.

## Analytical Techniques

Two independent methods, one based on historical streamflow data, the other based jointly on streamflow meteorological data and precipitation forecasts, were used to analyze the risks of possible serious water shortages. The first simulated the operation of the reservoir using historical streamflow data and assuming varying rates of water withdrawal for water supply. A 39-year long (1938-1976) historical record of streamflows to the reservoir was pieced together using data from the several gauging stations, past and present, within the Occoquan Basin. For the period 1928-1938, the USGS gauge record at Kelly's Ford on the Rappahannock was used to estimate inflows. This 49-year long record (1928-1976) was then adjusted to correct for historical changes in the watershed, including reservoir construction and increasing sewage treatment plant flows. The resulting record is a representation of the kinds of inflows to the reservoir which can be expected to occur in the future, in any given year.

However, this year has been very dry, and streamflows have been quite low. Due to the depletion of the groundwater which controls the base flow of the stream, flows in autumns and winters following dry summers are likely to be lower than flows following dry summers. Therefore, to construct a record representative of the flows which are likely to occur this year, years in which the summer flows were high were eliminated from the historical record.

The remaining years were used in a simulation of the operation of the reservoir. The reservoir was assumed to contain 2.45 billion gallons on October 1. For each year in the record, October inflow was added to that storage, and withdrawals (at an assumed rate) were subtracted to give the storage at the first of the November. November inflows and withdrawals were than added and subtracted to give storage on the first of December, and so on through the spring of the year. All of the storage levels are adjusted to reflect the additional inflow of 1.2 billion gallons of water from an assumed release of 1.5 billion gallons at Lake Manassas during October and November. The results of the simulation were plotted on probability paper to estimate the chance that those levels will occur this year. These results are presented in a later section.

The second technique was similar to the first, except that the record of streamflows likely to occur this year was generated using a groundwater model, historical rainfall and temperature records, and long-range precipitation forecasts. Basically, this model uses six hourly rainfall data and calculates how much of that rain runs off directly and how much is absorbed by the soil. It also calculates how much of the soil moisture is lost to evapotranspiration, how much is contributed to streamflow, and how much goes to groundwater during each six-hour period. The result is a record of streamflow and soil moisture levels.

This model was calibrated for the Occoquan watershed by adjusting its parameters so that historical rainfall data, when processed by the model, reproduced historical streamflow records for the period 1947-1956. Later years were not used in the calibration, since gauging records in the Occoquan seem inconsistent with gauging records in nearby streams during part of that period. To test the calibration, rainfall records for March-September, 1977 were processed by the model, and the predicted streamflows were compared to reported streamflows for that period. The 1977 streamflow data was provided by the Virginia State Water Control Board. The fit was excellent, and the model accurately predicted relatively small inflow that occurred from the early October rains.

Since the calibration test run so accurately reproduced the observed streamflow data, the soil moisture information given by the model for conditions at the end of the run are almost certain to reflect the soil moisture and groundwater conditions which exist at the present time.

Historical rainfall data (1948-1975) were then run through the model to produce a streamflow record. In order to insure that every year in the streamflow record represented flows that could occur this year, the groundwater conditions in the model were reset to the present groundwater conditions on October 17th of each year (the day of the model runs). This streamflow record was then used in a simulation of the operation of the reservoir, identical to the simulation performed using the selected historical streamflow record in the first technique. Again, adjustments were made for sewage flow, upstream reservoirs, and purchase of water from Lake Manassas.

## The Current Situation

The factor with the greatest immediate influence on the current situation is the extremely low moisture content of the soils in the Occoquan Basin. The NWS streamflow model indicated a soil moisture deficit of five inches on October 1. This was the largest deficit in the 27-year record. The above normal rains of early October reduced this deficit to four inches, still extremely dry, although not quite the driest mid-October situation on record.

Significant runoff from gentle rains will not occur until the soil moisture deficit is reduced to the one inch level. Such a reduction would require at least four inches of gentle rain over a short period, and more than that amount if spread over a longer period. Therefore, with the exception of runoff from intense rains (which soak the upper layer of soil and then begin to cause runoff) and runoff from impervious areas, little runoff will be generated by rains well into December. It is worth noting that present groundwater conditions are significantly drier than they were in 1966, the year with the lowest November, December, and January flows in the data base for the NWS model.

The NWS is predicting that rainfall for the period mid-October to mid-November will be above average for this area. This increases the chances from 50-50 to 55-45 that total rainfall will exceed the historical average. Because the increase in the probability of rain is only slight, and because of the importance of rain intensity as opposed to total rainfall, the forecast does not alter the risk of serious drought this year. Long range forecasting information has been fully utilized in the risk analysis.

## Results of the Risk Analysis

The results of the risk analysis are summarized in Table 1. There is approximately a 10% chance that the reservoir will fall to the 1.1 billion gallon level if the current rate of water production from the Occoquan (about 40 MGD) is not reduced. This is the probability after the completion of water purchases from Lake Manassas. 1.1 billion gallons in the reservoir is the level (88 ft.) at which Fairfax County has stated it will declare a Stage III emergency and ban all uses of water not essential to life, health, and safety.

The risks of falling to other levels without demand reduction are also given in Table 1. Seven hundred million gallons is the top of the lowest major intake at the dam. If the reservoir falls below this level, the FCWA will begin to experience operational problems in removing water from the dam. 1.7 billion gallons is the level at which a Stage II-C emergency is to be declared. Stage II-C is the first to impact commercial establishments and public activities such as athletic programs.

The reverse of the risk analysis also holds, i.e., there is about a 90% chance that, even with no demand reduction, a Stage III emergency will not be required. Ten per cent is a significant risk, however, when people's jobs are at stake. Appropriate measures should be taken to reduce that risk.

It is worthwhile to note that without reductions in the production rate at Occoquan, droughts in the historical record would have caused Stage III emergencies. The effects of the 1930 drought are illustrated in Figure 1. With production reduced to 32 MGD, no such emergencies would have occurred.

## Effects of Demand Reductions

The study next determined how large a reduction in production would be required to reduce the risk to acceptable levels. Several levels of production were tested. It was found that at a production level of 32 MGD (8 MGD below the current level), the risk of a Stage III shortage is about 3% (see Table 2). This represents a reduction in per capita consumption of about 12 gallons per person per day. Thirty-two MGD seems to be a reasonable balance between inconvenience to FCWA customers and the risk of possible severe service curtailments.

## Recommended Action Plan

It is recommended that immediate action be taken to reduce production at the Occoquan Water Treatment Facilities to 32 MGD. This is not an extreme reduction, and might be achieved through an aggressive information and education program.

Additionally, Figure 2 shows a curve of storage in the reservoir against time. This curve was drawn such that if reservoir levels rose above the storage shown on the curve on a given date, a less than 1% chance of a Stage III emergency exists. Conservation should be maintained until this storage curve is exceeded. At such time as the storage rises above this curve, conservation measures can safely be relaxed.

Analysis indicate that if the above program is followed, the current emergency has a 50% chance of being over by early December. The possibility of ending the emergency improves rapidly after that.

The USGS, NWS, and ICPRB will continue to cooperatively assess the risk situation on a weekly basis. Should the risk of curtailments increase due to continued drought, new target production figures at the reservoir will be recommended.

## TABLE 1

PROBABILITIES OF FALLING BELOW STORAGE LEVELS
AT 40 MGD (CURRENT PRODUCTION RATE) AT OCCOQUAN*

| | | | |
|---|---|---|---|
| Storage Level | 93 feet | 88 feet | 83 feet |
| Volume of Storage Remaining | 1.7 B.G. | 1.1 B.G. | 0.7 B.G. |
| Probability | 13% | 10% | 8% |

* Purchase of 1.5 B.G. from Lake Manassas is assumed.

## TABLE 2

PROBABILITY OF FALLING BELOW STORAGE LEVELS
AT 32 MGD PRODUCTION AT OCCOQUAN*

| | | | |
|---|---|---|---|
| Storage Level | 93 feet | 88 feet | 83 feet |
| Volume of Storage Remaining | 1.7 B.G. | 1.1 B.G. | 0.7 B.G. |
| Probability | 5% | 3% | 2% |

* Purchase of 1.5 B.G. from Lake Manassas is assumed.

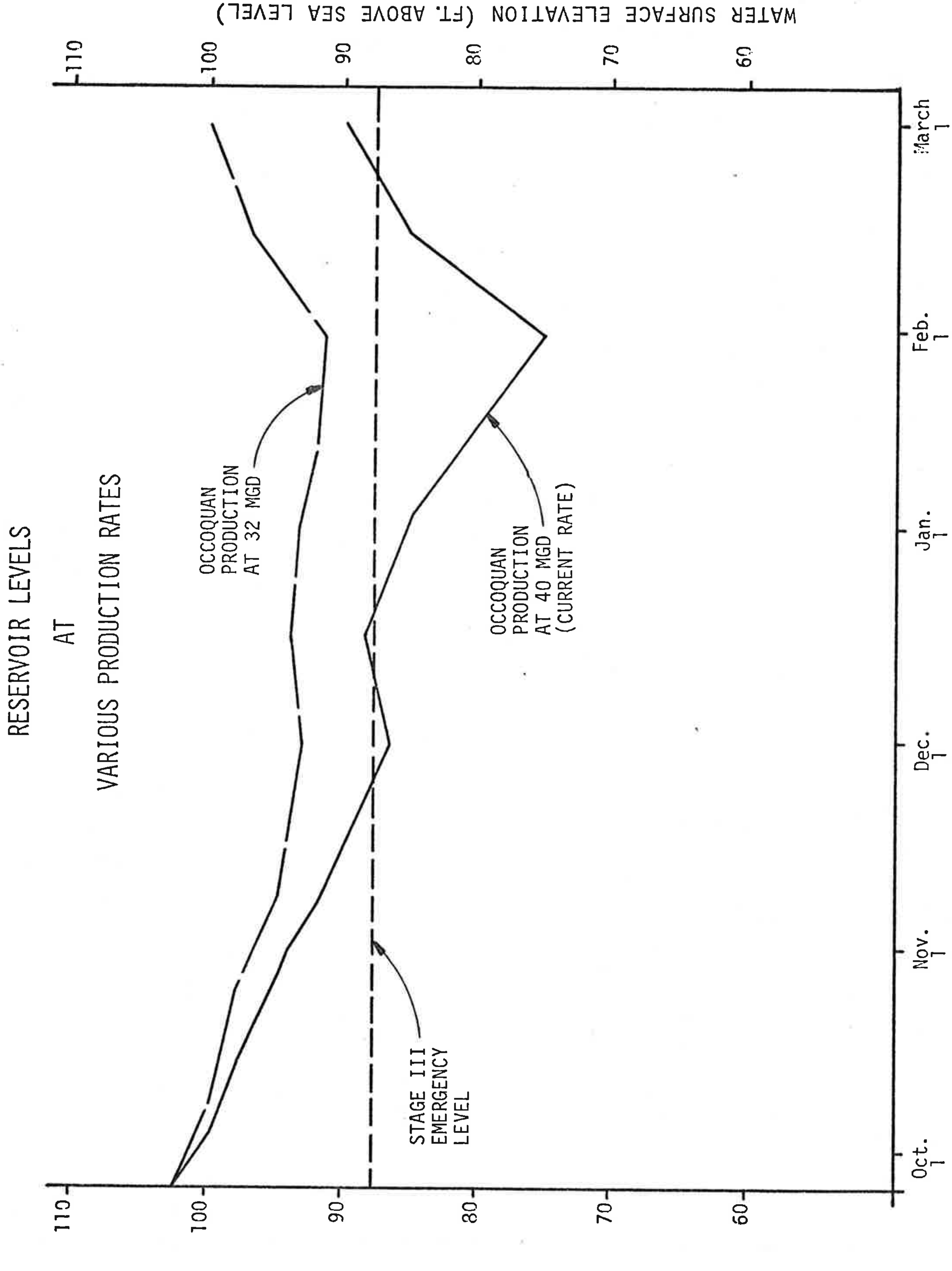

RESERVOIR LEVELS
AT
VARIOUS PRODUCTION RATES
WATER SURFACE ELEVATION (FT. ABOVE SEA LEVEL)
110
100
90
80
70
60
OCCOQUAN PRODUCTION AT 32 MGD
OCCOQUAN PRODUCTION AT 40 MGD (CURRENT RATE)
STAGE III EMERGENCY LEVEL
Oct. 1
Nov. 1
Dec. 1
Jan. 1
Feb. 1
March 1



FIGURE 1

# OCCOQUAN TARGET STORAGE CURVE

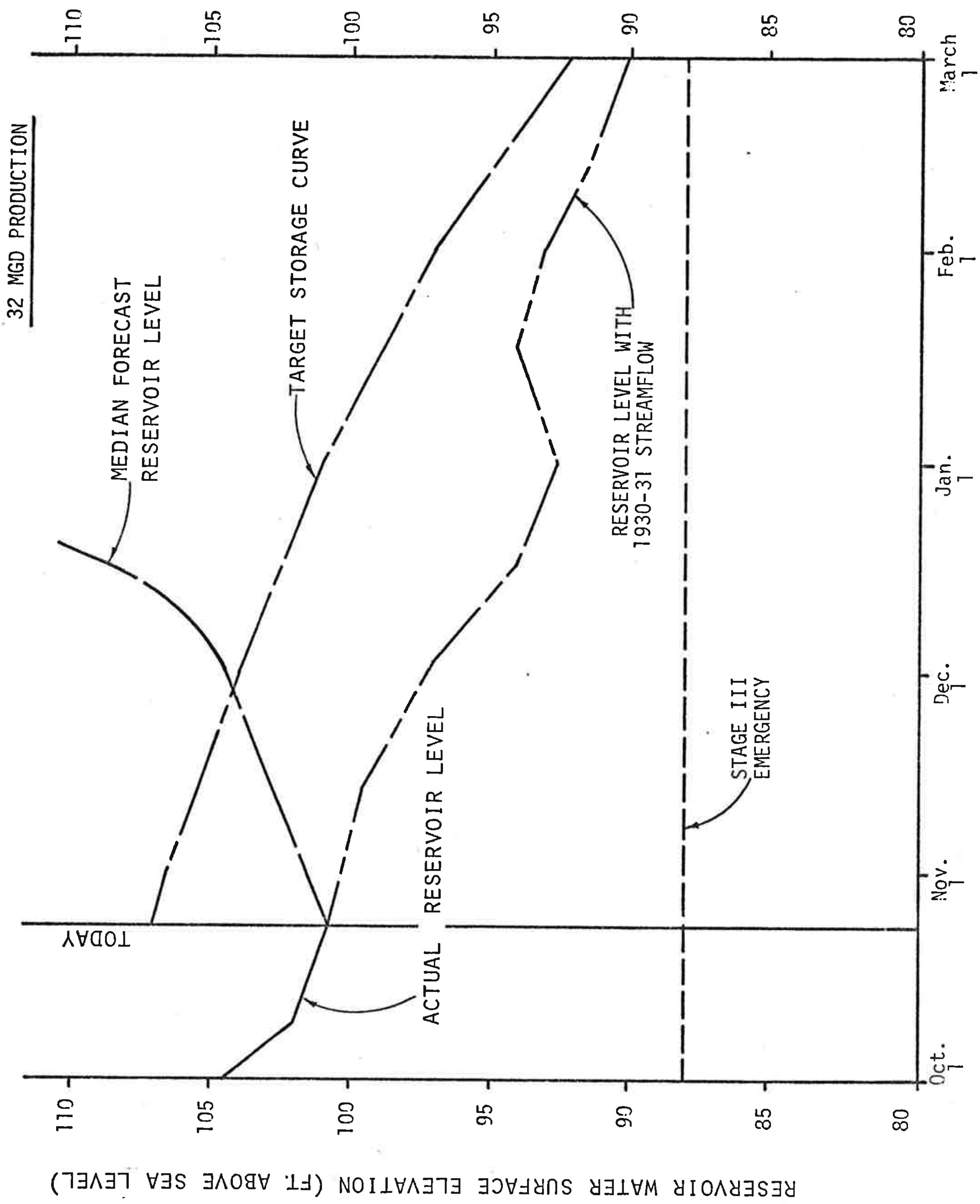





FIGURE 2

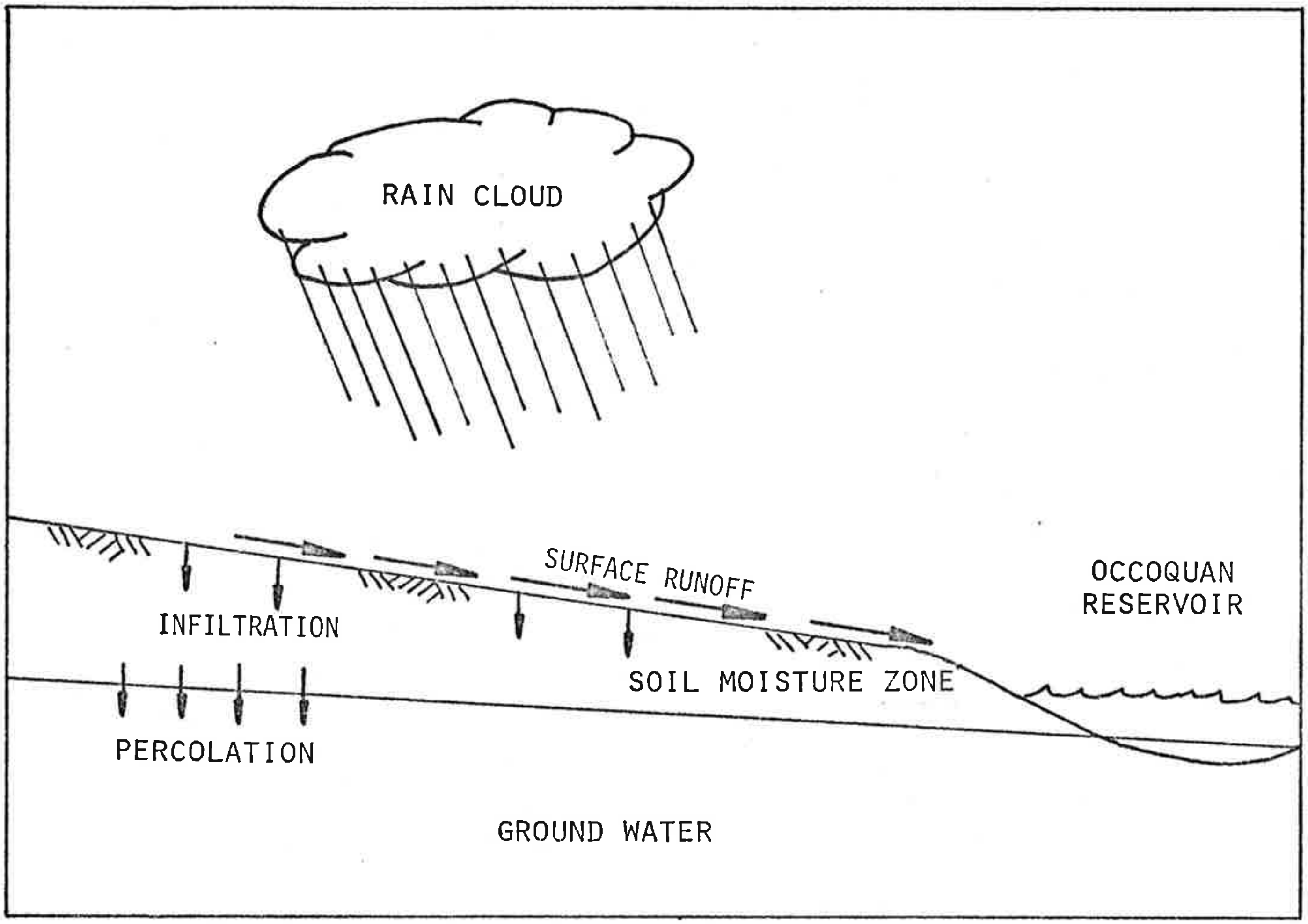
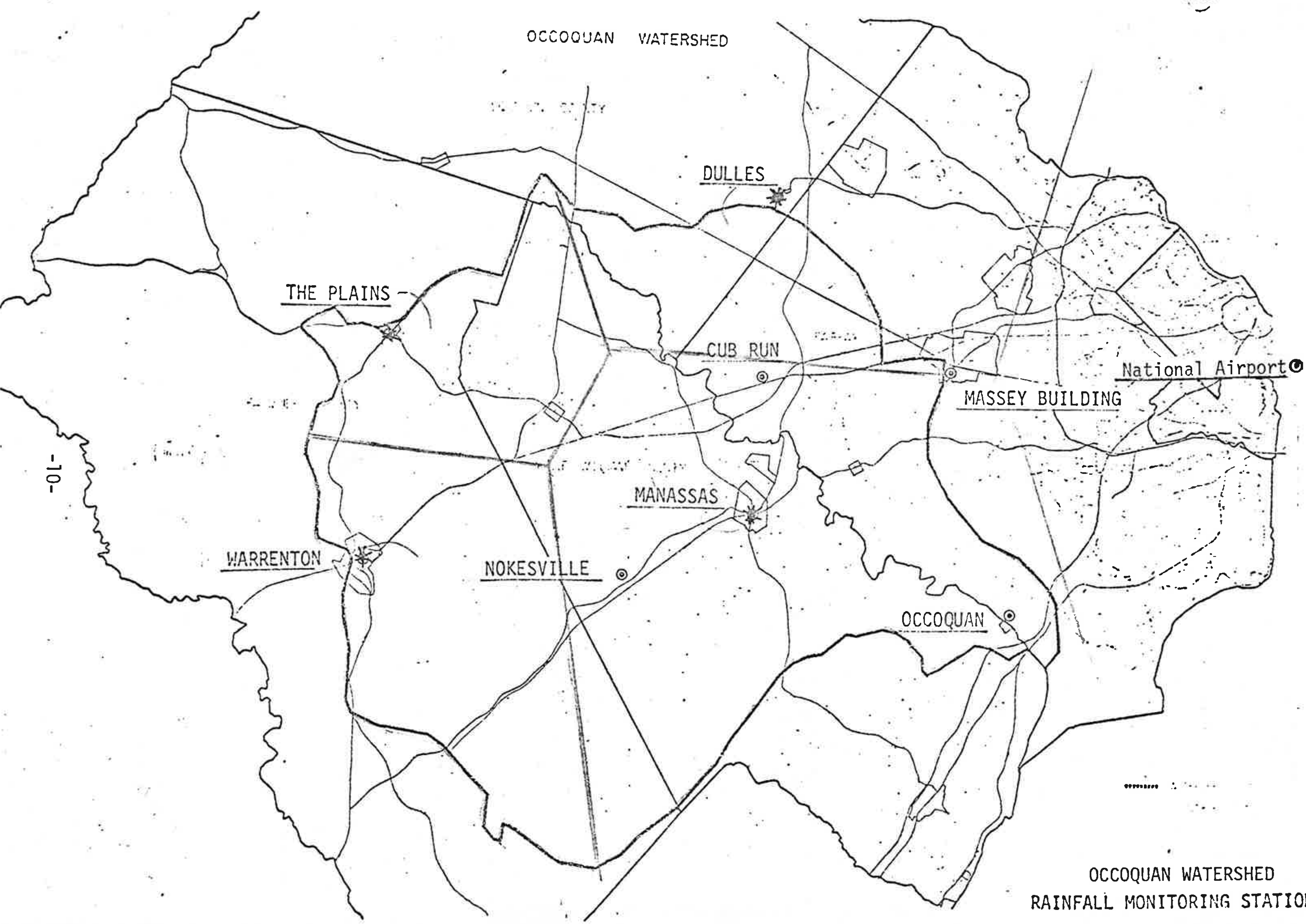

RAIN CLOUD
SURFACE RUNOFF
OCCOQUAN
RESERVOIR
INFILTRATION
SOIL MOISTURE ZONE
PERCOLATION
GROUND WATER



FIGURE 3




OCCOQUAN WATERSHED
RAINFALL MONITORING STATIONS