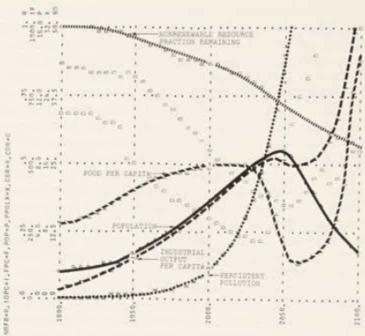

Figure 7-18 Run 7-13: recycling technologies
The advances in resource exploration and extraction technologies of Run 7-12 are supplemented by an improvement in recycling technologies that reduces per capita resource usage by a factor of eight in 1975. That policy removes the constraining effects of resource depletion and allows population and capital growth to continue until checked by persistent pollution.

We chose to model the implementation of recycling technologies as a change in NRUF because increased recycling does not necessarily change the amount of materials in use at any time for each person. Recycling merely changes the source of the materials, reducing the rate of decline of virgin nonrenewable resources. Because we hypothesized a causal link between per capita material usage and per capita pollution, increased recycling does not necessarily mean that less pollution will be generated. A reduction in the PCRUMT values, on the other hand, would represent the effects of a policy change that would reduce both resource usage and pollution generation. An example of a change that would be represented by shifting the PCRUMT table would be a significant increase in the use of smaller cars that consume less gasoline (a nonrenewable resource) and thus release less lead into the environment (a persistent pollutant).

One might expect the policies implemented in Run 7-13 to extend the period of continued growth in the model by effectively eliminating resource depletion as a limitation to growth. The resulting behavior shown in Run 7-13 does show that resource depletion no longer suppresses growth as in Run 7-12, but the basic over-

shoot and decline mode of behavior is still evident. The removal of the resource constraint allows the system to continue its growth until the level of persistent pollution becomes the limiting constraint.

In Run 7-13 industrial output IO and industrial output per capita IOPC continue to grow beyond the levels reached in Run 7-12. These higher levels of output generate enough persistent pollution to interfere significantly with the persistent pollution absorption process. As a result, the positive loop relating the level of persistent pollutants PPOL, the pollution assimilation half-life AHL, and the persistent pollution assimilation rate PPASR becomes active. The higher the level of persistent pollutants, the longer the assimilation half-life of those pollutants and the lower the assimilation rate. The decrease in the persistent pollution assimilation rate tends to increase the level of persistent pollutants still further. Run 7-13 shows that persistent pollutants accumulate quite rapidly once the positive loop becomes active, exceeding by 32 times the 1970 level of pollution in the year 2050. The high level of persistent pollutants generates side effects that eventually force both population POP and industrial output per capita IOPC to decline after the year 2050.

As the level of persistent pollution rises above its 1970 level, the rate of degradation of land fertility increases, causing land yields to decrease after 2030. The increase in industrial output adds to air pollution, which also decreases land yields, so that food per capita FPC decreases sharply after 2030. The increasing index of persistent pollutants PPOLX also tends to decrease the life expectancy of the population through the lifetime multiplier from persistent pollution. The combined effects of decreases in the lifetime multipliers from food and from pollution force the population POP to decline steadily after 2050 in Run 7-13.

As food per capita FPC declines after 2030, the agriculture sector demands more of the available industrial output to achieve an increase in land yields. The increasing allocation of industrial output away from the industrial sector and into the agriculture sector decreases the reinvestment of industrial output in industrial capital and forces the growth of industrial output to halt after 2050. Note that the last decades before the year 2100 show a startling recovery in the indicators of material well-being (industrial output per capita IOPC and food per capita FPC), although the pollution level remains extremely high. The recovery occurs through the following mechanism: as the decline in population gains momentum after the year 2000, the population begins to decrease faster than the total output of food and industrial goods. As a result, per capita food and industrial output again start to rise. The higher food availability per person indicates that smaller allocations of industrial output to agriculture are necessary, and the surplus is used to fuel growth in industrial production. Industrial output again begins to grow, making even more resources available for the production of food and goods.

The decline and recovery are accentuated by the seemingly unimportant assumption that allocations to the maintenance of land fertility are reduced when food is extremely scarce, as embodied in the relationship describing the fraction of agricultural inputs allocated to land maintenance FALM. The link between total food production F, food per capita FPC, the fraction allocated to land maintenance FALM, and