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WATER RESOURCES IN THE SOVIET UNION: TRENDS AND PROSPECTS

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ABSTRACT

Soviet growth has placed heavy demands on its water resources. As in capitalist countries, rapid economic development has been accompanied by declines in the quality of the USSR's natural resources. Plans to continue high rates of investment ensure that the problems will worsen unless major efforts are made to meet the challenge. In view of the USSR's relatively limited water endowment, dramatic plans have been made, including serious consideration of immense water diversion schemes.

This paper surveys and evaluates trends in Soviet water use. It then examines the impact of the Soviet economic structure on the severity of water resource problems. Simple models of firm behavior indicate that environmental destruction by a Soviet firm may be greater than that by its capitalist counterpart. These microeconomic problems carry over to an aggregate level in view of the national emphasis on construction and industry. Given the critical need for fresh water, the Soviet response has been to plan massive water treatment and diversion projects.

1. INTRODUCTION

Soviet growth has placed heavy demands on its water resources. In particular, agricultural and economic expansion along the water-scarce southern rim of the USSR have created major water resource problems. Anticipated future growth will increase the severity of the problems in the absence of substantial corrective measures. Indeed, water constraints may slow development considerably in the southern USSR unless measures are taken. This paper examines the effects of Soviet industrialization on its water resources, and then considers the impact of the Soviet incentive structure on this relationship.

The 11th Five Year Plan (1981-1985) aims for industrial output increases of 26-28% for both capital and consumer goods, with substantial increases in thermal electric, hydroelectric and atomic power capabilities plus concurrent expansion in agricultural output and acreage ([60], p. 16). For the hydroelectric turbines to spin, the agricultural areas to produce crops, the atomic power reactors to cool, and the industrial sector to provide output, fresh and plentiful water is essential. Yet the Soviet Union does not enjoy a relatively abundant water endowment. Its 16% of the earth's land mass has only 10-11% of the fresh water runoff.[1] Moreover, while the European and Volga

[1] See M. Goldman [16], pp. 78-79; B. Babich *et al.* [3], p. 1.

Basins of the USSR contain about 80% of the country's population, 90% of its arable land, and generate almost 80% of its industrial output, they contain only 24% of the total water resources. Of the 4300 km^3 annual run-off, over 80% drains into the Arctic Sea and the Pacific Ocean. The 27% of the USSR considered to be the most arid holds only 2% of its water resources. The water distribution disparity is further emphasized when one considers that Siberia has over 155,000 rivers compared to the European Russia's 45,000. Most importantly, 70% of the Soviet Union annually risks the potential of drought due to limited rainfall and resultant low stream flows.

While a country cannot alter its fundamental resource constraints, it can alter those additional ones created by its social structure. In principle, public ownership of the means of production can lead to an efficient use of scarce environmental resources, with firms paying an appropriate shadow price for the natural resources they consume or destroy. In reality, the Soviet incentive structure may generate even greater environmental destruction than would occur in a similar situation characterized by unregulated capitalism. The reward structure facing a Soviet manager offers little reason for him to conserve resources of any sort, including scarce water resources.

Section 4 discusses models of Soviet firm behavior in greater detail. We first turn to a discussion of the trends and extent of Soviet water use (Section 2) and follow by considering the problems that have ensued (Section 3). Section 5 concludes with a summary of the problems and consideration of likely future prospects.

2. WATER USE AND WATER PLANS IN THE SOVIET UNION

The Soviet Union's plans for economic expansion coupled with rapid urban growth will make a strained water supply even tighter. Overall industrial output for the USSR increased 17 times between 1940-1975 with the Western Siberian Economic Region and the Kazakhstan Economic Region experiencing respective increases of 31 and 27 times.[2] The development of previously undeveloped or marginal agricultural land will add further to the Soviet water burden. With these industrial and agricultural increases the quantity of water demanded will rise accordingly.

Roughly half of the water used from lakes, rivers, reservoirs and streams is used for irrigation, while unreclaimed water consumption in agriculture exceeds 70% of the total.[3] In 1980, total Soviet water use was roughly 396 km^3, while the total used in irrigation in 1979 was 180 km^3.[4] The extent of needless water loss is staggering in view of the severe water constraints in the southern USSR, Kelley et al. ([25], p. 79) report that only half of water tapped for irrigation reaches the fields, and that only half of this latter amount is recovered for reuse. Similar figures are reported in Gustafson ([19], p. 126), and the losses are attributed in large part to seepage due to

[2] See F. Martyaev [34], pp. 24-25. The two regions comprise a major portion of the rapidly growing, water scarce parts of the USSR.

[3] P. Poletaev [42] pp. 11-12. D. Kelley et al. [25] report that a comparable 46% of US water use went to agriculture around 1970, though that proportion was expected to rise considerably in the coming decade.

[4] The 1980 figure is given by P. Poletaev [43], p. 9; the irrigation figure is provided by G. Kiryanov [27], p. 10.

unlined canals and ditches. Descriptions of irrigated areas also suggest that the productivity of water use could be raised by improvements in field design.

Growth in total water use has been dramatic. Between 1950-1970, water consumption in industrial uses quadrupled, while its use in agriculture doubled. The 170-200 km^3 1970 Soviet water use had doubled by 1980, and another 200 km^3 increase was projected to occur by 1985.[5]

With this increased demand for water resources, the ecological strains caused by each new factory or sown hectare will intensify, barring remedial measures. The Soviet Union has already exacerbated its water resource problems with the concentration of heavy and light industry, food production plants, and other industrial enterprises within 11 river basins in the European and southern regions--the Volga, Dnepr, Dnestr, Don, Kuban, Ural, Terek, Sulak, Kura, Amu Darya, and Syr Darya--that flow in part through arid or semi-arid regions.[6] This has resulted in a series of environmental problems stemming from increased effluent levels, the continued dumping of raw sewage, inadequate water recycling and purification facilities, excessive costs for wastewater and sewage treatment plants, pesticide and fertilizer run-off, increased municipal demands, and greater soil erosion. Of the problems that resulted, scarcity of fresh water availability for irrigation was by far the most important. However, dramatic declines in commercial fishing, a cholera outbreak, and fear of regional environmental havoc with the continued drying up of the Aral Sea all helped to focus Soviet concern.[7]

These problems have in fact led to an increased determination by the Soviet Union to protect its environment. This new awareness has been followed in recent years by declarations affirming the protection of nature by an effort to improve technological levels of wastewater and sewage facilities and speed their construction, and by an 11 billion ruble allocation in the 11th FYP for environmental protection.[8] In addition, a number of plans have emerged to help improve the environment by diverting parts of the flows of Arctic-bound rivers from the north to the southern areas of inadequate moisture.

Water problems in the Soviet Union stem in large part from the nation's agricultural inefficiencies. The Soviets have promoted an agricultural program that emphasizes rapid expansion of sown area and the opening of large amounts of potentially productive land. This strategy has been fairly water (as well as other input) intensive, and relatively labor saving. The lack of an appropriate incentive structure that has rendered *sovkhoz* and *kolkhoz* cultivation less productive in terms of output/ha. (despite probably using more non-labor inputs/ha.) than private cultivation effectively has lead to the substitution of water, fertilizer and capital for labor effort in agricultural production. At the same time, it seems likely that labor underemployment in the rural Soviet Union is relatively common (especially outside of the planting and harvesting seasons). With half of the nation's water supply devoted to irrigation, it is apparent that the demand for water could be reduced greatly if the underemployed labor force were induced to exert effort in water conservation practices.

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[5] The figures are given in M. Goldman [16], p. 80, and are attributed to the Soviet economist S. Oziranskii.

[6] B. Babich *et al.* [3], p. 1.

[7] For a detailed discussion, see T. Gustafson [19], Ch. 3.

[8] I. Il'ev [22], p. 3.

Soviet policy, however, has pushed largely in a different direction, reflecting the ability of central planners to take advantage of opportunities offered by non 'incrementalist solutions."[9] The most grandiose of all water conservation plans involve the Caspian Sea. To counter the falling level of the Caspian, the Soviets have evolved a series of plans designed to stem the decline. These plans range from diverting more water to the Volga, to an incredibly complex set of plans that would divert water from either the Sea of Azov, the Ob and Yenisei Rivers in Siberia, or from various northern European Russian rivers that empty into the Arctic Sea.[10] As Micklin notes ([35], p. 73) "the quantity of water diverted by these schemes would be immense: up to 315, 250 and 42 cubic kilometers annually from Siberian rivers, the Azov Sea, and the Pechora and Vychegda, respectively."

While these projects are vast, though within the scope of the Soviet technological ability, the environmental consequences of the Kama-Vychegda Project which would involve numerous canals, hydroelectric stations, new reservoirs, the river diversion are uncertain. Global geographers' warnings of potentially major climatic changes do not appear to have impressed greatly the Soviet leadership. Other Soviet plans for the Caspian Sea include diking certain sections of the sea in an effort to reduce losses from evaporation and restoring some of the lost breeding waters of commercially valuable fish. The parts of the Caspian that were under consideration were both the Northern Caspian, where damage has been particularly great, and the Gulf of Kara-Boguz-Gol.

The least complicated plan of all the river diversion or diking schemes involved diking the Gulf of Kara-Boguz-Gol, and this plan in fact has been implemented. On March 4, 1979, the flow of the water between the Caspian and Kara-Boguz-Gol was halted with the erection of a dam.[11] The dam was implemented under the premise that the rapid evaporation of water through the gulf, estimated to be as much as 5-6 km^3 annually, could be prevented.[12] In 1979, after the strait had been successfully dammed, plans were made to provide a lock system for the dam. Scientists had cautioned that if the flow of the strait was completely blocked, the gulf would dry up within 3-5 years, and that the resulting economic costs would be substantial.[13] Because of the unique nature of the gulf, surface and underground brines containing numerous rich deposits of hydrous, raw material would be depleted: Izvestiia reported that a cubic kilometer of Caspian-Kara-Boguz Gol water contained up to 13 million tons of salts, chemical compounds, and rare earth elements.[14]

Apparently, the plans for the lock system for the dam were either shelved or proper funds were not allocated, as calls for emergency measures to save Kara-Boguz-Gol were reported in early 1983.[15] Moreover, the earlier predictions of the scientists are being realized. Since the construction of the dam, the size of the gulf has decreased by two-thirds and it now covers only 6000 km^2 as opposed to 18,000 km^2 three years earlier. The depth of the gulf has dropped as well from a former 2-3 meters to half a meter. Also as predicted, this shrinkage has resulted in a deterioration in the quality of the

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[9] This advantage is noted in an article generally skeptical of the advantages possed by centrally planned economies in dealing with environmental issues. C. Zeigler [71], p. 132.

[10] This discussion draws largely from P. Micklin [35].

[11] V. Gavrichkin, [14], p. 19.

[12] P., Micklin ([35], p. 71), though, reports that savings would be only 4 km^3.

[13] V. Gavrichkin [14], p. 20.

[14] A. Grachev, [18], p. 27.

[15] The discussion in this and in the following paragraph draws on Grachev [18].

extracted salts, chemical compounds, and minerals. The cost of production process have both increased. In addition to the immediate economic costs, other environmental problems have resulted, and these will eventually impose further costs. The loss of 12,000 km^2 of water surface has caused a drastic change in the local area. Agricultural areas are becoming increasingly salinized and "even birds are avoiding the lifeless waste."[16] Interdepartmental disputes have arisen between the Ministry of Land Reclamation and Water Resources' Volgogradstroi Association and the Ministry of Chemical Industry over who should bear the cost of the installation of a lock. Both refuse to allocate funds for the project. In the meantime, Kara-Boguz-Gol becomes smaller, and may become the first water body in the USSR to disappear.

Due to the poor planning and a failure to heed the warning of concerned scientists, the Soviet Union may have created a secondary problem that rivals the first. The level of the Caspian began to rise in 1978. This rise has been attributed to the Caspian's centuries-old tendency to fluctuate in depth. A new problem has emerged as harbor facilities, wharves, piers, and adjoining settlements have been flooded by the rising water level. Thus, while the Soviets recognized and tried to rectify the original problem of the shrinking Caspian, shifting trends have made man's efforts counterproductive, at least in the short run.

Not all efforts to augment stream flow or raise water body levels have been as dramatic as the plans to raise the Caspian. A less enormous but still "non-incremental" plan involves Lake Sevan, one of the Soviet Union's most beautiful lakes, situated high in the Armenian Caucasus. The Soviets have completed the first stage of their plans to supply the lake with more water and replace the 24 km^3 that were used to construct the Sevan-Razdan cascade of irrigation and hydroelectric stations.[17] In March 1981, a 48.3 km. tunnel through the Caucasus mountains at a height of 1900-2600 m was finished, and the Arpa River began to contribute part of its flow to the lake. Despite completion of the tunnel, the Seven had dropped 18 meters with the development of the cascade of power and irrigation stations. Soviet scientists have calculated that the lake's level needs to be raised 4-5 meters to restore the lake's former thermobiological conditons, and that the lake must be restored to its former depth within 20 years if the lakes' special trout, the ishkhan, is not to become extinct. Prior to WWII, 5000 centners of ishkhan were taken; the catch has dropped now to 60 centners.

The Arpa-Seven tunnel is expected to transport annually up to 250 m^3 (.25 km^3) of water. This quantity implies an average flow of $8m^3$/sec,while the desired flow of $25m^3$/sec can be attained only during the high period of the spring run-off. Lake Sevan also receives water from the Elgis River, which contributes 50 million m^3/year. Future plans to improve Lake Sevan call for an eight kilometer tunnel to stretch from the Vorotan River, and a combined flow diversion of the Getik and Marmarik Rivers that will contribute annually 200 and 80 million m^3 of water, respectively. If no additional water is taken from Lake Sevan,then it can be expected to return to its former height in approximately 41 to 45 years from the date of completion of the plans.[18] Thus,

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[16] Ibid., p. 27.

[17] The discussion of the Sevan is based on O. Popov [45], p. 17 and Yu. Arakelyan, [2], p. 21.

[18] If water loss from evaporation is exactly offset by rainfall and by the inflow from the Elgis, new increments from the Arpa, Vorotan, Getik and Marmarik Rivers will lead to an annual gain of .53km^3; this increment will replace the initial 24 km^3 loss after 45 years(ignoring changes in evaporation). If the flow from the Elgis is considered part of the increment, the original level

while calculations indicate that Lake Sevan cannot fill as fast as intended, it is also apparent that the USSR had made a definite commitment to improve the lake.

In addition to the attempts to replenish Lake Sevan's water, efforts are being made also to decrease pollution levels. In 1978, the construction of biological sewage treatment plants began in bordering cities and towns and construction of industrial facilities in the immediate proximity has been forbidden.[19] The supervision of water used for irrigation also has been placed under stricter guidelines. In late 1978, the CPSU Central Committee and USSR Council of Ministries instructed the Armenian Republic Council of Ministers to take steps to insure the complete halt of untreated effluent discharge into the lake by 1985.[20]

While the diversion of the Arpa to Lake Sevan has been a significant accomplishment, its scope is rather small in comparison to current plans being considered to divert water to the most water-scarce areas in the European, southern, and central Asian parts of the Soviet Union. As these plans will have environmental impacts as great as any engineering projects being considered throughout the world, they have provoked both domestic and international controversy. Soviet water resource specialists have estimated that by 1985, if the climate and water use trends continue, the water deficit in the lower Volga River and Aral, Azov, and Caspian Sea basins could reach 130 km^3. The major water distribution and diversion plans completed in the past have involved sacrifices from the Volga and Dnepr basins.[21] Now, it is these basins that are in need of water. The diversion of the Volga and the Dnepr are incapable of providing for all of the short run requirements of water needs, let alone the long run requirements.

The Volga's role in redistributing Soviet water resources is central to many plans. In response to a mandate from the CPSU 25th Congress, the USSR Academy of Sciences has recommended the diversion of about 20 km^3/year of water from northern rivers to augment the Volga's flow, thereby offsetting the 20km^3/year presently taken irretrievably from the Volga.[22] The increased flow into the Volga will, in turn, raise the level of the Caspian Sea.

However, not all of this additional flow is likely to wind up in the Caspian, as there is pressure as well to divert water (up to 6 km^3/year) from the Volga to the Don, thereby raising the level of the Sea of Azov.[23] Freshwater flows into the Azov have diminished, with mineralized Black Sea water thereupon flowing in through the Kerch Strait. As is discussed in the following section, the Azov's increased mineral content has had negative ecological and economic impacts in the Azov basin.

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will be restored in 41 years. Obviously, variation in evaporation rates due to changing surface area will have some impact on the restoration date, as will variation in the completion dates of the plans' components.

[19] Pravda [46], p. 24.

[20] Izvestiia, [23]. Unfortunately, the striking gap between directives and realized outcomes offers little confidence that these timetables will be met. Construction of water purification plants are notorious for their delays, while the time tables in directives regarding discharges generally are viewed to be flexible. Detailed discussions on these points appear in T. Gustafson [19], [20] and D. Kelley [26].

[21] N. Nekrasov and N. Razin, [38], p. 1.

[22] G. Voropayev, [64], p. 6.

[23] Yu. Zhdanov, et. al., [72], pp. 6-7.

The plans for diverting northern water headed toward the Barents Sea to the Volga are conceptually simple, but require huge amounts of capital, labor, and time. Many variants of the diversion schemes exist, and the purpose here is not to evaluate all of them, but to show the immensity of the projects.[24] The plans for diversion of the northern rivers have several similar major features and are distinguished by a multitude of varying details. A prominent plan, even greater in scale than the Academy of Sciences' proposal, envisions routing about 50 km^3 of water from the Northern Dvina and Onega River to the Volga. N. Nekrasov and N. Razin of the USSR Academy of Sciences comment that "diversion on this scale will require the construction of high capacity pumping stations and tests of the capacity of rivers and canals along the route."[25] Yet another plan that has been around in some form for quite a while is best known as the Kama-Vychgda-Pechora reversal scheme.[26] It involves damming both the Vychegda and the Pechora Rivers with the construction of canals and pumping stations to transport the water to the Kama River. The water would finally enter the Volga where the Kama intersects the larger river. The KVP project was initially formulated as being primarily a hydropower scheme, and was to have flooded 15,000 km^2 of land--a far larger area than in later designs. Opposition from scientists in the Komi ASSR, the site of the area to be flooded, were joined by the oil and natural gas industry, who feared the inundation of valuable fields. Nevertheless, the 25th Party Congress declaration suggests that some diversion project is quite likely.

Even greater diversion schemes have also been considered for areas east of the Volga. One scheme involves redirecting part of the flow of the Ob and Yenisei Rivers in western Siberia to Kazakhstan and other central Asian republics.[27] Water supply problems occur frequently in Central Asia, and the area is subject to drought. The Toktogul Hydroelectric Power Station did not operate for a "long time" because of the inadequate flow of the Naryn River.[28] The plans for the redirection of the Siberian rivers are truly massive, and involve the diversion of about 25 km^3 year:

> "The plan calls for beginning the diversion at the village of Belogoye on the Ob. The main canal will start at the confluence of the Vagai and Irtysh Rivers and will run south across the Irtysh-Tobol floodplain. Then it crosses the valley of the Ubagan river, moving toward the Turgai Gates on the Irtysh- Syr Darya divide. Along this route, the water is raised to a height of about 100 meters by four stages of pumping stations on the Lower Irtysh hydraulic-engineering complexes and four stages on the canal itself. After passing the plateau of the Turgai divide, the canal will follow the right bank of the Turgai river into the Tengiz Reservoir, with a planned capacity of 14 cubic kilometers which will regulate an even low rate of water. From there the diversion route moves to the southeast, crosses the Syr Darya River near the Syr Darya-Amu Darya interfluve, enters the Amu Darya in the Kara-Kalpak Autonomous Republic at the foot of the southern slope of the Sultanuizdag Mountains.[29]

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[24] A more detailed discussion of competing reversal schemes appear in T. Gustafson [19], Ch. 5.

[25] N. Nekrasov and N. Razin, [38], p. 1.

[26] This discussion draws heavily on T. Gustafson [19], Ch. 5.

[27] N. Nekrasov and N. Razin, [38], p. 2.

[28] Ibid., p. 2.

[29] Ibid.,pp. 2-3. See also V.A.Skornayakov and I. Ye. Timashev [58]. Var-

The finished canal will be 2270 km long with an average width of 120-170 meters and an average depth of 12 meters. The environmental and ecological consequences are highly uncertain, but may well be substantial. There has been some opposition from geographers and others with environmental interests, though opposition from the oil and gas industry and the enormity of the project's expense probably have been more effective deterrents. However, despite the limits to man's understanding of major environmental phenomena indicated by recent efforts to control the Caspian Sea, one finds little hesitation in the writings of the proponents of diversion.

The needs to further expand agricultural production in the semi-arid central Asian plains, and to provide water to the rapidly growing central Asian population make some Asian diversion scheme virtually inevitable in the eyes of Soviet planners.[30] Given the agricultural needs, the land loss due to wide-scale construction of hydroelectric power stations with their river flood plains is striking and ironic. Komarov ([30], p. 57) claims that 120,000 km^2 have been flooded. Even given that much of the land lost was unusable, it is clear that huge tracts of fertile land have been sacrificed. The Kuibyshev "Sea" on the Volga alone submerged 20,000 km^2, while an additional 11,700 km^2 have become silted and swampy.[31] Thus the USSR's early crash electrification programs have proven costly in the long run, necessitating further expansion in the dry southern rim, and hence further watercourse alteration schemes.

River diversion and water resource distribution both require canals to transport the precious liquid, and the number of waterways within the Soviet Union is increasing annually. Hundreds have been constructed for irrigation, to transport water to desired areas, and to further inland shipping and transport. Canals everywhere face problems of water loss through seepage and evaporation and it is difficult to assess whether these problems are unusually severe in the Soviet Union. Losses stemming from evaporation are largely unavoidable, but the degree of seepage can vary due to the construction of the canal's lining and the underlying soil structure. One of the most serious examples of water loss in the Soviet Union occurs in the Kara-Kum Canal that runs through the desert in Turkmenistan, near the Afghan border. The Kara-Kum, which receives 10 km^3/year of water from the Amu Darya, loses 2.5 km^3 from seepage through the sand.[32] This loss is ten times the amount of water that Lake Sevan receives from the Arpa. To deal with this predicament, a procedure has been developed that injects a clay solution possessing a small amount of polyacylic plastic into the ground under the canal. The end product is a protection shield 30 centimeters thick that has been claimed to have reduced water losses by 94% in treated sections of the canal. Concrete lining of new canals is also becoming common (Gustafson [19], p. 131).

Canals have been instrumental in opening up vast tracts of new land for agriculture, and great quantities of water have been diverted for irrigation. However, at least in some instances, the utilization of canal water has been limited by striking administrative problems. The following examples may not be representative, but to the extent that they even partially characterize the efficiency of irrigation water use in central Asia and Siberia, it seems likely that a large portion of the scarce water available is wasted.

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iants of the Irtysh reversal scheme (referred to as the "Anti-Irtysh") exist with different degrees of scale, cost and environmental impact.

[30] See T. Gustafson [19], Chapter 5.

[31] Komarov [30], p. 57. Gustafson ([19], p. 47) reports that 23,000 km^2 of agricultural land have been flooded.

[32] N. Morozov, [37], p. 20. As noted, other estimates of water loss are as high as 40-50%. (T. Gustafson [19], p. 126: D. Kelley et al. [25], p. 79).

The 182 km. Kalunda Canal in the southwest Siberian steppe was built in the late 1970s to open up new land for agriculture through the provision of water for irrigation.[33] Yet its development was hurt by inefficient planning and resource management. While the canal's construction was able to proceed on pace, the operations that supported its extension fell far behind. The most crucial of these operations were the repair shops for machinery. Other problems complicated the situation: labor turnover was 50% each year due to inadequate living facilities; earth-moving and transporting equipment was not used to capacity; the construction of a concrete plant to provide materials was so behind that its projected start-up date and the canal's finishing date coincided; although local gravel was available, crushed rock was shipped in instead, resulting in frequent shipping delays; the integration of the canal with its irrigation projects was not guaranteed due to the lack of a clear delineation being made in developmental responsibility among concerned ministries; the canal maintenance staff had no qualified engineers; finally, machine operators and mechanics were in short supply.

Both the Kulunda and Irtysh-Dzhezkazgan Canals serve as small-scale models for testing the feasibility of diverting Siberian rivers to central Asia. Neither the construction problems nor the lack of administrative coordination encountered bode well for major river diversion projects. The Irtysh-Dzhezkazgan was started in order to provide ore enriching mills and metallurgical plants with water.[34] The canal's length was planned to be at least 1000 km., stretching from the Irtysh River in western Siberia to industrial cities in central Kazakhstan. The water drained from the Irtysh was to be raised 0.5 kilometers by a series of powerful pumping stations in an artificial channel that leads to a set of regulating dams and storage reservoirs.

However, problems have arisen throughout its construction. The canal reached the mining city of Karaganda in 1972 only to find that the city had failed to construct connecting pipelines and pollution control facilities. As of 1978, difficulties that had arisen included a complex tangle of funding shortages resulting from the lack of a clear, functional statement of responsibilities and deadlines among participating ministries and concerns. Unsurprisingly, industrial complexes built with the expectations of obtaining water from the canal, but completed well before the canal's arrival also experienced high operating costs. There has been difficulty as well in achieving the simultaneous completion of the canal and projects that will utilize its water. While Karazahl, a city built to develop ore under the premise of the canal's water being available required water to be brought in by truck, lags in planning and designing adjoining agro-towns postponed their projected development and construction to 1985. Further, in areas that the canal has reached, poor irrigation methods already have led to the salinization of the soil. Finally, as an example of incoherent coordination, during the canals' construction the Karaganda Province party authorities decided to develop a fledgling meat industry in an arid region hundreds of kilometers from the canal.

It is expected that the Irtysh-Dzhezkazgan will, upon completion, have as much as 850 million m^3 of water throughout its system. The Irtysh River, though, is not exactly a raging torrent at its point of intersection with the canal. From its source all the way to Omsk, the total contribution of its

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[33] This discussion draws on V. Sapov, [52], pp. 8-9.

[34] This discussion draws on M. Poltoranin and V. Sevastyanov, [44], pp. 11-12.

tributaries in the hot summer months ranges between 140 and 180 m^3/sec.[35] The demands on the Irtysh along with the droughts between 1974-78 have resulted in major declines in the river level. Due to the importance of shipping and navigation, the pace of dredging efforts has picked up and the channel has been deepened, so that the current's speed has increased and the water level has fallen even further. Consequently, there is now a canal under construction to divert the flow of the Ob River and interesect the Irtysh near Pavlodar.

The problems involving the use of the Irtysh-Dzhezkazgan's irrigation waters appear to be representative of the Soviet land reclamation experience. Vast areas have been made suitable for cultivation (90,000 km^2 in the 1971-75 9th FYP alone: see Gustafson [19], p. 124). Yet agricultural land loss has been commensurate (see D. Kelley et al. [25], pp. 225,84), largely reflecting the abandonment of salinized land. To meet output targets, the Ministry of Reclamation and Water Management (Minvodkhoz) has constructed vast lengths of waterways.[36] Unfortunately, the incentive structure does not reward waterway quality or maintenance, and the result has been that the waterways built function poorly. Coordination between the Ministry of Agriculture, responsible for developing the reclaimed area for farming, and Minvodkhoz has been poor as well, and funding for capital inputs complementary to irrigation water appears to be suboptimal.[37]

In summary, needs to irrigate agricultural land, provide water for growing central Asia and generate power have given water diversion schemes an important role in Soviet development plans. Ecological consequences of past industrial and environmental policies have been severe as well, and have made water diversion still more critical. Unfortunately, efforts to date on smaller projects suggest neither that more massive diversion projects will be achieved without problems, nor that use of the diverted flows will be highly effective.

3. WATER USE AND WATER QUALITY

Having considered Soviet water use trends and plans for making available additional water resources, we turn now to an assessment of Soviet development on the quality of its water resources. In view of the fragile nature of support offered by an arid ecosystem for modern industrial and agricultural economy, it is unsurprising that the environmental consequences have been severe. Indeed, much of the rationale for the Volga diversion schemes involves restoring the environment around the southern seas.

The Caspian and the Aral Seas were once treasure troves of the inland Soviet fishing industry. However, fish harvests have declined considerably with the rapid industrialization of the river basins, indicating that the environment is changing rapidly. Both the Aral and Caspian are fed by two major rivers. The Caspian obtains the majority of its water from the Volga and Ural rivers, with over 70% of the flow coming from the Volga, while the Aral is fed by the Amu Darya and the Syr Darya. Both seas have exceptionally high evaporation rates, since they are located in the arid southwest, though neither has any tributaries that offset the inflows.

Between 1930 and 1965, the surface area of the Caspian shrank 2,450 km^2.[38] Because of the Caspian's unique nature, some fluctuation in size has been experienced in the past, but the regular drop in the sea's level and surface area is

[35] V. Kiryasov and V. Mezentsen, [29], p. 1. At that flow rate, it would require roughly two months to supply 850m m^3 of water.

[36] This discussion draws heavily on T. Gustafson [19], Ch.9.

[37] Ibid., p. 127.

[38] M. Goldman, [16], p. 219.

consistent with the intense industrial, agricultural, municipal, and irrigational demands put upon the Ural and the Volga. In the late 1920's and early 1930's, the Caspian reportedly received 32.5 km^3 of water annually. Now the sea receives only 5-6 km^3 annually, and it is clear that the shortfall is increasing.[39] Within this 35 year period from 1930 to 1965 the total annual catches of the local fishing industry have dropped from 600,000 metric tons to 100,000 metric tons.[40] The composition of the catch has worsened as well, with species of low commercial value replacing the cherished and once plentiful sturgeon, as well as whitefish, salmon, and herring.

The economic effects of the Caspian's recession have been considerable. With a 25% reduction in the northern Caspian's area, many ports either have become dysfunctional, or provisions have had to be made to open a channel or more communities further inland. In addition to decreasing the water inflow into the Caspian, Soviet industrialization has led to a deterioration in that water's quality.

In the early 1970's, Goldman ([16], p. 231) estimated that the Volga carried 70% of all effluents in the Soviet Union. At this time, boxes, rotten watermelons and muskmelons, and city garbage used to float on the surface of the Volga. Due to the high concentration of petroleum and oil refineries situated on the river, the Volga caught fire at least once. Komarov reports that as of 1978, the midstream oil concentration of the Volga was 25-30 times the MPC ("maximum permissible concentration": the Soviet standard for effluents).[41] It is claimed that the floating trash and oil slicks are a thing of the past, and, given the priority received by the Volga in the Soviet water quality improvement program, it is plausible that its pollution levels are decreasing.[42] Yet it is unlikely that pollution levels in the Caspian are experiencing a corresponding drop, given the partially cumulative effect of pollution on seas, along with an increased pollutant load due to agricultural wash-out.

The Aral Sea is similar to the Caspian in that it is shrinking due to an inflow drop in recent years of 30 to 80%.[43] In 1977-78, the average annual water resources in the Aral Sea basin was estimated to be 127 km^3, of which the Aral once received around 58 km^3.[44] Calculations have indicated that the only part of the Aral remaining in 20 years will be two salt lakes.[45] The average depth of the Aral has dropped 7 meters since 1963. As of 1979, the Aral's volume has declined from a 1946-50 level of 1062 km^3 to 758 km^3; surface area has fallen from 66,000 km^2 to 52,000 km^2, and its salinity has nearly doubled.[46] Recent water demands for irrigation, coupled with poor drainage schemes and diversion to areas beyond the Aral drainage basin have resulted in the virtual elimination of inflow from the Syr Darya, a traditional contributor of 13 km^3.

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[39] V. Gavrichkin [14], p. 20. Unfortunately these figures do not appear to be consistent with the flows reported in P. Micklin [35], pp. 69,71. Nevertheless, there is no disagreement concerning rates of change of water inflow.

[40] P. Micklin [35], p. 69.

[41] B. Komarov [30], p. 37.

[42] T. Gustafson [20], pp. 457-459.

[43] See B. Babich, V. Lozansky and A. Kuzin. A series on tributary inflow is given in A.A. Rafikov, [49], 1983, p. 346.

[44] I. Rusinov [51], p. 17. V.M. Borovskiy [5], 1980, p. 63 and A.A. Rafikor [49], 1983, p. 345.

[45] Ye. Fyodorov [11], pp. 5-6.

[46] A. Yurits, [69], p. 13, V.M. Borovskiy [5], 1980, p. 63, and A.A. Rafikov [49], 1983~~. Also see Kuznetsov, et.al [32]~~,1981.

The Aral's decline has resulted from removal of water from the Amu Darya and Syr Darya for large-scale irrigation projects that figure prominently in the region's economic development. Since 1979, the Amu Darya or its tributarities have received the additional burden of several major construction projects that are finished or under construction: the Navoi State Regional Power Station, new chemical and petroleum-refining plants in Chardzhov and Bukhara, poultry factories in Taknatash, agricultural facilities in Nukus, light industry in Tashavz, Urgut, and Kataub, and agricultural facilities in Termez.[47] The Syr Darya's waters will, upon the plants' completion, be used for the Syr Darya State Regional Power Station, a poultry factory in Kyzl Orda, a metallurgy plant near Tashkent, chemical and petroleum refineries in Almalyk and Fergana, light industry in Kyzl Orda and near Tashkent, and the extensive development of various agricultural facilities within the river basin. Irrigated area in Central Asia and Southern Kazakhstan grew from 55,000 km^2 in the mid 1960s to 70,000 km^2 by 1980 and is still projected to grow by another 25,000 km^2 in the near future, requiring an additional 35 km^3 of water.

It appears from dispassionate accounts of Soviet water use plans that planners are resigned to the Aral's drying up (or at least a continuation of the process until Siberian water becomes available) despite the resulting desertification of a large area in the eastern Aral basin, soil damage to still larger areas from deposits from erosion of dried sea bed, and loss of commercial fishing in the Aral (see Borovskiy [5], 1980). The entire environmental effects of the Caspian and Aral's continued disappearance are unknown. The quantity of water in a given area not only effects the quantity evaporated, but alters the rainfall patterns as well. Because of the Caspian's decreased surface area, Micklin claims that "the climate along the northern and northwestern coasts has become more continental and desert conditions have intruded into the Eastern portion of the Volga basin", and that there is growing evidence that the sukhovei (transcaspian desert winds) are occuring at increased intervals.[48] Furthermore, with large parts of what was once sea exposed to the wind, it is possible that massive salt deposits will be transported to nearby agricultural area and damage croplands.

The Sea of Azov is yet another Soviet "sea" that has encountered severe environmental problems. The Azov's depth has dropped by over 2 meters in recent years, while its salinity has increased by nearly 30%[49]. Due to the fall in the Azov's level an increased quantity of Black Sea water has entered through the Kerch Strait. As the basins of the tributary Kuban and Don rivers are among the most industrialized in the Soviet Union, it is unsurprising that industry and agricultural wash-out have contributed heavily to the Azov's pollution.[50] While the level of oil pollution in the Black Sea is admittedly high, the Azov's oil content has been measured to exceed

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[47] This discussion is based on four articles translated in the Current Digest of the Soviet Press (hereafter CDSP) from Pravda, all entitled "The USSR Under Construction." See [47d], p. 14.

[48] P. Micklin [35], p. 70.

[49] B. Komarov [30], pp. 28, 41. The salinity has also been increased by the annual discharge into the Azov of 3 million tons of salt and salt compounds from other sources.

[50] ZumBrunnen([73], p. 49) estimates for the early 1970s that 7 million m^3 of effluent were dumped annually into the Don.

the larger sea's by many times. Water samples taken from the Azov often contain 100 MPC's of oil and between 40-50 MPC's of phenol and zinc.[51]

The combined effects of higher salinity, decreased water flow from its tributaries, and increased pollution levels have decimated the productive capacity of the Azov. Because of the salinity, the DO content has dropped and there are less food sources for fish. At one time, the Azov was the most productive body of water in Russia, yielding nearly three times the combined output of the Capsian, Baltic, and Black Seas. However, in recent years the catch has dropped to one ninetieth of its peak abundance. The fish that are left cluster near the river deltas, and (as is true for the Caspian) the quality of the fish in commercial terms has dropped.[52]

Pollution from numerous industrial enterprises and heavy urban concentrations along its rivers, tributaries also have affected the Black Sea. The sea, along with the Azov, is the eventual destination rivers that carry the wastes of vast industrial regions of the southwestern USSR. Komarov ([30], p. 37-38) cites reports for 1978 that the entire resort and health area stretching from Odessa to Batumi was polluted with oil, phenyl and bacterial contaminants. ZumBrunnen ([73], pp. 35, 43) chronicles the plight of the Black Sea drainage basin between the early 60's and 70's, and reports that pollution rendered the Ingulets, Saksagan, and Byk river tributaries devoid of life. Problems were compounded by inadequate or non-existent industrial and municipal purification and treatment facilities. Along the Black Sea coast there were 200 locations in 1970 where wastewater was released without having undergone any treatment.[53]

Soviet industrialization has also affected its lakes, though not typically as dramatically as its southern "seas". The lake that has received the greatest attention from concerned Soviet environmentalists is the earth's largest fresh-water lake, Lake Baikal. Located in southcentral Siberia, the lake is a crescent that extends for 636 km. with an average width of 47.8 km. Baikal receives water from 336 rivers but has only one outlet, the Angara River. The lake is thought to be the world's oldest (at 25-30 million years), contains 1500 unique plant and animal species, and is known to be the deepest with a maximum depth of 1620 meters. Estimates of Baikal's percentage of world fresh-water range from 2.5% to 20%.[54] The lake is a source of national pride, and is referred to by various Soviet authors as "our glorious sea" and "Siberia's blue pearl," which must be protected "like the apple of one's eye". The lake is (was) exceptional in both its transparency and purity and possesses an extraordinarily rich DO content of 12-14mg/l.

The problems of Baikal began in the late 1950's and early 1960's when the USSR began to develop great Siberia. The decision to locate industry in the vicinity of Baikal was made in 1957.[55] In 1966, the first of two pulp and paper mills and accompanying communities sprang up on the shores of Baikal.

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[51] B. Komarov [30], p. 38. The discussion in the following paragraph is also based on this source, pp. 38-41.

[52] Komarov [30] regards the Azov as comparable to Lake Erie, except that the former has yet to exhibit areas of eutrophication.

[53] C. ZumBrunnen [73], p. 58.

[54] This discussion is based on G.I. Galaziy [14]; T. Gustafson [19], ZumBrunnen [74], pp. 81-85; M. Goldman [16], p. 179; V. Yermolayev [67], p. 7; and V.Yermolayev [68], p. 9.

[55] See C. ZumBrunnen [74], p. 83 and M. Goldman [15], p. 316.

The nearby town of Baikalsk started emitting over 60 million cubic meters of effluent destined for the lake. The decision to develop Baikal touched off a wide-spread debate (the first of its kind in the USSR) as environmentalists, academicians, and scientists vigorously protested.

Proponents of development proclaimed the USSR's need to develop its economy and exploit its resources, and offered assurance that effluents would be properly treated. Environmentalists remained suspicious and vocal in opposition, fearing that even limited development or industrialization would irrepairably harm the lake and its endemic flora and fauna, while products made by the polluting industries could be synthesized elsewhere. The pro-industrialization forces prevailed, while making concessions by promising to provide the best in purification facilities. Modern facilities were in fact constructed, albeit with some delay and relaxation of effluent standards.[56] Felled logs ceased to be floated down Lake Baikal's tributaries, as it became apparent that whitefish spawning grounds were destroyed in the process.[57] However, logs are still collected at the river mouths and rafted across Lake Baikal, thereby still hindering the spawning run, while sunken logs contribute large quantities of organic material to the lake.

In recent years, the city of Ulan Ude on Baikals' Selenga River tributary has continued to develop. A food processing plant, light industry, and the paper, pulp and lumber industry are expanding.[58] Komarov ([30], p.33) claims that polychlorinated biphenyls (PCB) were found in Lake Baikal in 1976. Yet as ZumBrunnen ([74], p. 81) points out, despite its problems Lake Baikal remains clean by the standards of lakes in developed areas, more comparable to Lake Superior or Lake Tahoe than Lake Erie. Whether its purity will withstand the region's projected industrial development and the nearby Baikal-Amur Mainline railroad remains uncertain.[59]

Another well-known lake that faces serious environmental problems is Lake Issyk-Kul. Issyk-Kul, located 1608m above sea level in the Kirgiz Republic with a surface area of 6200 km^2, is an all-Union resort that expects to receive over 1m visitors annually by 1990. Between 1910 and 1970, the lake's depth declined 3.3 meters, but dropped 3 more meters in the ten years between 1971-1981.[60]Soviet scientists now anticipate that it will drop another 3-4 meters in the next few decades, with its shoreline creeping inwards by 500-1000 meters. Already, the water loss figures suggest that the lake has become smaller by about 3-400 km^2. The recent annual water shortfall of .4 to .45 km^3 is generated by over 500 industrial, municipal, consumer service, and agricultural enterprises in the area. As in the case of Lake Baikal Issyk-Kul has also suffered from growing pollution and an apparent

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[56] Thus, the mills' effluents are now drinkable (C. ZumBrunnen [74], p. 113), but leading Soviet environmentalists still criticize the standards set as being too lax (G. Galaziy [13], pp. 218, 220). Ironically, the pulp and paper industry's original justification for setting up the plants--to use the lake's exceptionally pure water in rayon production, thus greatly reducing demineralization costs--became obsolete before the plants were completed, as the Soviet tire industry began switching to nylon. Thus the Baikal's mill now also produces paper and turpentine. See T. Gustafson [19], pp. 40-44.

[57] Destruction of the spawning grounds and short-sighted fishing practices have combined to nearly decimate the whitefish catch and impair its commercial viability. See C. ZumBrunnen [74], pp. 100-103.

[58] Pravda [47b], p. 11. Another form of pollution potentially detrimental to Baikal comes from the estimated 6,000-10,000 speedboats that traverse the lake. See M. Mikhalkov [36], p. 19.

[59] A pessimistic assessment is given by T. Gustafson [19], p. 45.

[60] This discussion draws on O. Losoto and V. Shirokov [32], pp. 10-11,

indifference from the main polluters. The sewage system of the nearby city of Przhevalsk began in 1969, but was still under construction in 1978.[61]

The Aral, Azov, Baltic, Black, and Caspian Seas along with the lakes of the Soviet Union are depositories for pollution from industrial development, agricultural nutrient wash-out, oil leakage and spills, and limited sewage treatment. The rivers of the USSR are, in turn, the transporters of most effluent loads, and often are highly polluted. The rivers of densely populated European Russia are especially susceptible to high pollution levels, resulting from the increased industrial effluent load, agricultural wash-out of both organic and inorganic substances, and a reduced flow resulting from hydro-electric dams and extensive irrigation demands.

Accounts of degradation of major Soviet rivers have been striking and indicate the limited extent of environmental concern maintained by planners and managers. All major rivers in central Asia have been dammed for irrigation or hydropower. Half of the Amu Darya's total flow and nearly all of the Syr Darya's is diverted for irrigation.[62] Massive construction and economic development plans such as the Baikal-Amur mainline appear to have been formulated with limited environmental considerations. Published warnings have followed in BAM's case, but it remains uncertain that planners will accept an 8-10% cost increase for even moderate environmental precautions.[63]

Virtually all major rivers have serious pollution problems as well. The Iset River in 1965, and the Volga in 1970 both caught fire after excessive amounts of oil had been released into them.[64] The Moscow River was considered dead by the early 1970's and no fish could be found within it.[65] The Byk River that ran through Kishniev, the capital of Moldavia, was reported to be almost an open sewer and to be black at its point of entry into the Dnestr.[66] The Dnestr itself has been regarded as being relatively clean in recent years (though see ZumBrunnen [73], pp. 35-8 for a discussion of its earlier problems), but recently experienced the disastrous spill of over 1 billion gallons of waste salts from a fertilizer plant after an earthen dam gave way.[67] Bush([6], p. 11) reports that 25 km^3 of untreated water are introduced annually into open reservoirs. The Siberian rivers are generally in better

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[61] Some lakes in the heavily populated western Soviet Union also suffer pollution, particularly from added nutrients. An example, that of 80 km^2 Lake Naroch in Belorussia, is given by L. Novikov [40]. Eutrophication, with increasing quantities of rushes and algae blooms, has occurred in shallow areas. The nutrient growth in this case stems from many sources: industrial wastes, agricultural runoff (exacerbated by nearby land reclamation projects), and poor sewage treatment facilities for the lake's many sanitoriums and vacation sites.

[62] Ye. Fyodorov, [12], p. 11.

[63] See V. V. Vorob'yev and A. T. Naprasnikov [63], p. 319.

[64] M. Goldman, [16], p. 108.

[65] A. Rubinov [50], p. 5.

[66] C. ZumBrunnen, [73], p. 33.

[67] S. Schmemann, [53], pp. 1, 11.

shape compared to their European and Southern counterparts, though their natural purification mechanism requires a much longer distance to function.

Our sketch of the Soviet Union's water resource management has focused on the environmental problems that have emerged in recent decades. It would be improper to fail to acknowledge the major efforts of recent years to improve the environment. In their 10th FYP, the USSR launched an attack on environmental problems and allocated 14 billion rubles to this cause, and reaffirmed their commitment to environmental improvement with an additional 11 billion ruble allocation in the current (11th) FYP.[68] In comparison with the motives for environmental programs in advanced capitalist countries, it seems fair to describe Soviet concern for their water resources as stemming from awareness of potential water constraints to further economic expansion, particulary along the southern rim, rather than from a strong conservationist drive by the Soviet leadership.

The Soviet strategy designed to improve the water resource base is highly integrated with plans to improve the distribution of Soviet water. These plans have several basic goals: 1) to concentrate pollution improvement in areas where alleviation is most critical (for example, the Moscow and Volga Rivers); 2) to provide all effluent-dumping industries with access to a wastewater treatment station or a closed cycle water system; 3) to eliminate the flow of raw sewage from municipalities into any river or sea; 4) to provide more water to critical areas by transporting it from areas of excess moisture (involving river diversion and canals) and 5) to find the "correct balance" between industrial, agricultural and environmental needs in regards to the distribution of fresh water. Severe fresh water shortages have forced the Soviet Union to consider both diversionary redistribution schemes and water-saving conservation measures, in which decreased pollution levels is an important component. Conservation goals overlap with the goals for pollution control, especially in the establishment of closed-system water use facilities for industry.

There is little doubt that Soviet environmental awareness has grown rapidly, and that environmental advocates have a degree of official support. Indeed, the relative fragility of the arid Soviet ecosystem ensure that planners cannot ignore the warnings of environmental scientists. There is a growing awareness in the USSR that failure to rationalize water resource utilization policies at best will add a costly drag on further economic growth, and at worst may invite one or several ecological disasters. In 1980 Leonid I. Brezhnev admitted"There was a time when the aim was to put a plant into operation as soon as possible at any price. Today, however, we must build in a way that will not be detrimental to nature, we must renovate old enterprises so that they will not be detrimental to the environment."[69] One of the prices to which Brezhnev referred was the almost unregulated dumping of waste that occurred prior to the 9th FYP. Unfortunately, public statements by Soviet leaders often characterize an unrealistic ideal rather than actual policy. Such discrepancies, along with the absence of highly systematic data, make it difficult to guage the Soviet Union's real progress in dealing with the correction of old environmental water abuse problems and the prevention of new

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[68] Gustafason [19], [20], presents a critical discussion of the Soviet environmental program.

[69] Cited in P. Poletaev [42], p. 10.

ones. While Western analysts are keenly aware of the growth in power of Soviet environmental interest groups, these groups' pressure may be more than counteracted by countervailing forces. In particular, desire to achieve continued output growth may limit the extent that investment funds will be channeled to environmental programs that do not remove potential production constraints. While maintenance of economic growth is likely to dictate water conservation programs in the southern USSR, the growth drive is likely to lead to environmental deterioration in the expanding areas in Siberia.

Among environmental achievements claimed, the dramatic improvement of the Moscow River is perhaps the most visible. Twenty species of fish are said to have returned to the once lifeless waters after the Soviets launched their environmental clean-up campaign in the capital's province.[70] Large water treatment plants have been constructed to meet the needs of the capital city. The Lyuberty Aeration plant and the Novokurynovo Station together can treat 5 million m^3 of water per day, so that since 1974, "no untreated water has entered the Moscow river." Much of the river's newly-returned health can be attributed to the creation of an industrial water supply system (the first in the USSR) and an increase in the number of waste recycling systems. Restrictions have also been passed for the Moscow Canal. Steamships have been prohibited from dumping, all wastes were required to be stored in containers, and 200 artificial spawning grounds were built.

Noted improvements in the Volga's water have also been observed.[71] Floating trash and oil slicks are no longer evident. However, the current treatment facilities involve primarily biological purification systems which fail to remove many chemical contaminants.

The Caspian Sea has also been targeted as a body of water in dire need of help. In 1978, the first of many water-treatment and conservation installations in the Caspian basin were put into operation. When all are eventually completed they will have a combined capacity of handling 3.2 million m^3 daily.[72] The Caspian Sea Petroleum enterprise has implemented measures to stem the oil pollution of the sea at its offshore rigs and this effort has been linked with more than 100 floating and shore purification facilities in and surrounding the Caspian. The tributary Ural River has also been a beneficiary of increased environmental protection and purification standards. Between 1976-81, 241m rubles have been invested in the protection of the Ural, and it is claimed that now "the Ural River has become incomparably purer...It's waters are saturated with DO, and their petroleum-product content...has been reduced to a fraction of its former level, and the concentration of permissible substances is within the permissible norms.[73] If this is indeed true, then the Ural has made a spectacular recovery. Additionally, 45 new water-recycling systems have

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[70]This discussion is based on (and the quotation below is taken from) A. Rubinov [50], p. 5.

[71]See R. Fyodorov [10], p. 18. Several other major rivers, including the Desna, have also been the targets of clean-up drives.

[72]This discussion is based on Y. Vodolazhsky [61].

[73]The statement was made by the Director of the Southern Ural Basin Territorial Administrations Hydrochemical Laboratory. See V. Shulgunev [55], p. 8.

started up in the Ural Basin, and the water-protection structures that have been built have eliminated or reduced the major polluters of the river.[74] The Ural, though, does not lack nearby polluting enterprises. Nor has all construction proceeded as planned: many purification plants need to be constructed or reconstructed, and deadlines for second-stage purification facilities have not been met. Moreover, the Ural remains subject to considerable pollution due to run-off from numerous livestock facilities containing untreated raw waste.

As water resources deteriorate and demand for fresh water grows, the Soviets have responded with more rapid construction of treatment facilities. In the 10th FYP, it was planned that wastewater treatment, and purification facilities with a total capcity of more than 35m m^3 would be commissioned, a 150% increase over the 9th FYP.[75] Some technological innovations have been implemented as well: examples given in the Soviet press include an effluent-free water supply system at the Chimkent Phosphorous plant.[76] This closed-system has limited the use of fresh water to providing only a cooling system. The Suoyarvi Cardboard factory has introduced a process which uses industrial effluents in box construction. Freshwater consumption has dropped 80% and the dumping of effluent into Lake Suoyarvi has been halted. The Verkhnedne-provsky Mining and Metallurgical Combine has come up with a purification and water-recycling system that has eliminated the dumping of sewage into the Dnepr.

Nonetheless, the Soviet problems of material allocation and construction that often run years behind schedule are well known. While water treatment, purification, and recycling plants are being built, the overall trend is not to fulfill plans on time in these construction areas. Construction of water resource protection facilities has lagged considerably, due to limited funding. The annual average allocation for capital investment in the wastewater treatment plants is 20% of the estimated total cost of the facility. At this slow pace, the construction that "according to the plan" will be completed in three years usually takes eight.[77] For example, in the Kuznetsk basin less than half of the 190 measures whose completion was targeted for 1978 had managed to be finished. For the coal industry, 19 of 61 planned treatment or purification facilities were built, in the metallurgical industry only 11 of 32, in the chemical industry only 6 of 15. More striking still, despite the limited funding available, the 150 million rubles spent on these projects comprised only half of the allocated total.[78]

Nor do problems end with the completion of a facility's construction, and examples of operational problems abound. The first stage pollution control installations on the Af River have been down for repairs since the moment they were completed.[79] In the Azov-Black Sea region, only 24 out of 5000 villages and towns had sewage systems in progress in 1980, but several of these 24 systems were not working due to a personnel shortage.[80]

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[74] This discussion draws on V. Shulgunev, [55] p. 8.

[75] B. Babich, V. Lozansky, A. Kuzin [3], p. 2.

[76] This discussion draws on Yu. Belichen'ko and V. Lubyako, [4], p.12.

[77] See K. Sharonov, [54], p. 20.

[78] G. Yurov, [70], p. 21

[79] Ibid., p. 21.

[80] G. Kiryanov, [28], pp.10,17.

It is difficult to ascertain the representativeness of the examples provided in the Soviet press regarding water quality and water treatment. Given the Soviet Union's rapid industrialization though, it is difficult to imagine that many water bodies in urbanized areas have avoided significant pollution. Moreover, examples of construction inadequacies are found over a wide geographic range. The problems also appear to stem from factors likely to apply to more than just a few specific projects, including low funding levels and an absence of administrative commitment. Even the well-intentioned, well-funded plant or city faces major operational constraints, since the USSR is characterized by severe shortages of ecological equipment and trained personnel.[81] Thus, it is plausible that the construction experience of water treatment facilities elsewhere in the Soviet Union is not dramatically better than for those discussed above.

4. WATER RESOURCE EXPLOITATION IN PLANNED AND MARKET ECONOMIES

The picture we have drawn thus far is of a nation that has placed great demands on its water resources, but that is now being forced to take some corrective steps. The steps to halt further ecological damage are restricted by two sets of constraints: those inherent in the Soviet economic system, and those inherent in the need to produce agricultural and industrial goods, regardless of the economic system. In this section we consider whether the Soviet economy might respond more sensitively to environmental destruction than will capitalist societies, or whether the Soviet system exacerbates environmental problems.

Unfortunately, this discussion must remain at an abstract level. Most Soviet environmental problems involving water resources have ecologically unique characteristics that hinder simplistic comparisons with other countries' environments. Nor, obviously, are all capitalist countries identical: even countries at similar levels of development for historical and political reasons may have greatly different levels of concern for their environment.[82]

While it is difficult to draw conclusions from a comparison water resource problems in the USSR and capitalist countries, there are some countries for which the comparison is also highly inappropriate. These countries are the traditionally highly developed countries--such as the USA, Canada, Australia, West Germany, France and Sweden--that have far higher living standards than does the USSR. As it is generally accepted both that income elasticities of demand for environmental goods and costs of provision of a clean environment will be higher in more developed countries, uncorrected comparisons fail to yield meaningful results (though this has not prevented the appearance of many comparisons). Moreover, the likely findings of any study that corrects for differences in costs of providing a clean environment (such as that the USSR neglects its environment relative to say, Sweden), would be most unsurprising. A more appropriate comparison would be between the USSR and Italy, Ireland, Spain or Greece.

Formally, a valid cross-country comparison of the relative environmental efficiency of two systems (ignoring aggregation and measurement problems) requires one first to know how social preference functions differ. Even if one knows preference structures, it is necessary to correct for differences in real income levels and in the opportunity cost of maintaining a given level of environmental quality. This cost schedule will itself depend on income levels, as well as on a country's particular geographic characteristics. Any such com-

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[81] See N. Feitel'man and I. Smagarinskii, [8], p. 14; T. Gustafson [20].

[82] See J. McIntyre and J. Thornton [33] for a discussion of the problems involved in cross-country environmental comparisons.

parison would require extremely careful construction, and is beyond the scope of this paper.

This section now considers how the environmental damage generated by an individual producer varies as the rules of the prevailing economic system vary. The economy-wide environmental quality differences generated by these micro behavioral differences are discussed briefly in the following section.

Consider an individual enterprise that produces a good Q from inputs of capital, K, and labor, L. This enterprise may be either factory or a farm, or it may be a producer of personal services. Assume further that in its production process the enterprise exploits the ambient environment, and in so doing reduces the quantity and/or quality of environmental goods (water, air, soil) available to the rest of society. In the case of water, the quantity may be effectively reduced if the firm's withdrawals from a stream exceed its discharges to the stream (due to evaporation, inclusion of water in the firm's product, or discharge of water into the ground that does not immediately return to the stream). Quality of the stream's water will also be reduced to the extent that the firm's discharges include nutrients and chemical pollutants, or alter the stream's temperature.

Assume a continuous production function for the firm that may be written $Q = Q(K,L,E)$, where E is an index of environmental dislocation stemming from the firm's production process. Such a function may be consistent with, but need not imply the "materials balance" constraint that matter can only be altered, and not created or destroyed. To keep the discussion as straightforward and intuitive as possible, we ignore complexities regarding irreversibility of environmental effects and precise depiction of an environmental damage function. Perhaps more importantly, we ignore difficulties that arise in representing what is properly a vector of environmental effects with a single index. Less critically, we do not distinguish between "use" and "dislocation" of the environment and environmental damage, implicitly assuming the latter to be a monotonically increasing function of the former. Although these considerations are important, they are unlikely to affect the qualitative conclusions drawn here.

We assume further that Q is a convex function of its inputs over the relevant range, and that $\partial Q/\partial E>0$ for sufficiently small amounts of E. That is, given amounts of capital and labor can be used to generate more output if the firm is willing to disturb the environment somewhat. We further assume that at some point the gain from additional environmental disturbance falls to zero; this restriction prevents firms from engaging in infinite amounts of environmental disruption. The propositions offered below are made with reference to the specific production function given in equation (1), but it can be shown that only the assumptions given thus far are necessary to drive the results.

For expositional clarity and mathematical simplicity, assume a simple relationship that incorporates the characteristics mentioned above, so that the firm's output can be written

$$Q = L^{\ell}E^{e} - dE^{b}. \qquad (1)$$

Capital use is temporarily ignored. Q is increasing in L and E, but for $e<b$ the output gain from further use of the environment eventually becomes zero and then negative. Even the most inconsiderate polluter will find a point at which operational changes leading to additional effluent discharges cannot be found that will, for a given labor force, generate additional output. In agriculture, water use eventually reduces rather than raises yields.

Consider the behavior of an entrepreneur in a market economy facing this production relationship. The standard assumption is that the entrepreneur will strive to maximize revenue, equal to price P times quantity Q, less costs. Costs in (1) simply equal the wage bill, the wage rate W times labor employed, L. Substituting in for Q from (1), the entrepreneur's maximand is thus:

$$\underset{\{L,E\}}{\mathrm{MAX}\pi} = P\cdot(L^{\ell}E^{e} - bE^{d}) - wL. \qquad (2)$$

Choice variables for the firm are the amount of labor hired, L, and the degree of environmental disturbance, E. Assuming that an interior solution is obtained and that $0<\ell, e<1$ and $e<d$ (hence Q_{LL} and Q_{EE} are both negative), the first order conditions can be solved for the desired level of E_1, E_1^*, as a function of L, product price P, and factor price W:

$$E^* = \left(\frac{e}{bd}\right)^{\frac{1}{d-e}} L^{\frac{\ell}{d-e}} \qquad (3)$$

Since desired L can also be expressed as a function of Q, W and P, we can substitute and express E* as a function of w and P:

$$E^* = \left(\frac{P\ell}{w}\right)^{\frac{\ell}{d-\ell d-e}} \left(\frac{e}{bd}\right)^{\frac{(1-\ell)}{d-\ell d-e}} \qquad (4)$$

For $d(1-\ell)-e>0$, then $dE^*/dP>0$ and $dE^*/dw<0$.[83]

The first finding is hardly surprising: if the price of the firm's product rises, output rises, and so does environmental disruption.[84] The second result is less obvious, and less general. As the cost of labor input rises, the firm economizes on labor use and further abuses the environment. However, total firm output also declines, leading to less of both factors being employed. In this case, the latter effect dominates, and declining production generates a net decline in environmental abuse as both costs rise.

These differentials enable us to draw an initial "second best" result. Compare the situation in which the firm in question is run by a private entrepreneur with one in which all inputs and outputs are directed by a social planner. Assume further that neither the entrepreneur nor the social planner recognizes the value of environmental preservation. Then the planner who wishes to maximize social welfare will choose inputs to maximize "shadow" profits, given the unit costs we assume for L and for E (zero by assumption). If w and P are identical for planner and entrepreneur, then so will be the degree of environmental disturbance.

In fact, the appropriate maximand for a Soviet enterprise or its parent ministry is difficult to judge. We consider several alternatives in this paper, none of which attach a weight in the maximand to environmental

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[83] It is necessary for $d(1-\ell) - e>0$ for the determinant of the total differential of the first order conditions (i.e., the Hessian determinant) to be negative definite; this in turn is a sufficient condition for profits to reach a maximum at the point where the first derivates equal zero.

[84] This level will exceed the socially optimal level degree of environmental disruption. However, unless the costs to society of losing a unit of E are so great that a corner solution is obtained (or social profits are negative at the efficiency point), some environmental disturbance will be socially desirable.

degradation. Such an assumption is an obvious oversimplification of a system that does contain a system of pollution control agencies with some enforcement powers (see K. Bush [6], T. Gustafson [19], and D. Kelley [26]).

However, the diffuse nature of environmental protection administration and the great social value attached to physical production limit the environmentalist constraints. Furthermore, while environmental groups may have some impact on the determination of plant location(or even if a particular plant is built), the evidence that they alter substantially the marginal behavior of existing plants is much weaker. We therefore proceed under the strong assumption that the Soviet manager is virtually unconstrained by environmental concerns.

In reality, capitalist societies usually impose a unit charge on water use (though this charge typically is not set with reference to a precise social value), but do not impose direct charges for damage done to the water used.[85] By contrast, the USSR imposes charges neither on water use nor for water quality degradation. As Bush ([6], p. 20) notes, Article 15 of the "Bases of Water Legislation in the USSR and Union Republics" mandates continued free water use, claiming that user charges would be too complex to administer. Like their western counterparts, though Soviet economists have pushed for the introduction of charges for a firm's consumption of scarce environmental socially-owned private goods. In their discussion of the need to calculate use of environmental goods in evaluating the enterprise cost of production, Feitel'man and Smagarinskii state bluntly:[86]

> "To date we have not yet elaborated a substantiated cost-accounting mechanism that would encourage production links to use natural resources in moderation. Therefore managers are unwilling to build nature conservation systems among existing production facilities, since under the present accounting system this will lead to the palpable worsening of cost-accounting indicators of basic activity."

From (4), if the wage paid by the entrepreneur exceeds the shadow wage due to the presence of payroll taxes, wage constraints, or the planners' recognition of unemployment, then the planned firm will produce more of the polluting output than an otherwise comparable capitalist firm, and in the process will pollute more. The planned firm will also generate higher E^* if the shadow price of output exceeds the producer's price, as would be the case if the firm were producing investment goods or necessities valued more by the planner than by the market in equilibrium. It can also be shown that the imposition of user charges for environmental goods such as water consumption faced by capitalists will lower a firms' optimal water consumption, and by lowering profits will also drive marginal firms from the industry altogether. In aggregate, if (as seems

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[85] Individual communities may zone out high-polluting industries, forcing such firms to be less choosy in picking a plant site. W. Fischel ("Fiscal and Environmental Considerations in the Location of Firms in Suburban Communities", in E. S. Mills and W.E. Oates, eds. Fiscal Zoning and Land Use Controls. Lexington MA.: Lexington Books, 1975) argues that these zoning laws compel highly polluting firms to locate in high property tax areas, thus imposing an indirect cost on them for their pollution. However, the cost thereby borne is unlikely to equal the entire social damage, unless their pollution is extremely localized in effect.

[86] [8], p. 15; Also see V. Fel'zenbaum [9]. Recognition of the problems in costing natural resources is widespread, and the articles appear in prominent journals (Feitel'man and Smagarinskii's piece appeared in Voprosi Ekonomiki, 1981, no. 11).

likely) Soviet priority sectors such as the capital goods and defense industries or agriculture are pollution-intensive relative to light consumer goods and personal services, then we should expect the USSR to generate greater environmental disruption than would a market economy with a similar resource endowment.

The expectation that the planned firm will cause greater environmental disturbance is not lessened if we assume that the capitalist firm has market power, and exercises it in a monopolistic or monopsonistic fashion. In the former case we now have $P = P(Q)$; $P'<0$. That is, the firm faces a downwards sloping demand curve, and is able to sell additional output only by lowering the good's price. The monopolist's use of the environment is:

$$E^*_M = \left[\frac{P\ell(1+\varepsilon)}{W}\right]^{\frac{\ell}{d-\ell d-e}} \left(\frac{e}{bd}\right)^{\frac{1-\ell}{d-\ell d-e}} \qquad (5)$$

where $\varepsilon = P'Q/P<0$, the inverse of the demand elasticity with respect to price, with a value greater than -1.[87]

The only difference between (4) and (5) is the appearance of the negative ε term in (5). The intuitive result is straightforward: the profit maximizing monopolist withholds production in order to drive up prices. While consumer surplus losses result, society does not suffer as greatly from environmental destruction in the monopolistic case. This result is hardly new, and can be dated at least to Hotelling's 1931 classic [21] on resource extraction. The monopsonistic case is similar. As long as the social planner has no reason to behave as a monopolist or monopsonist, then, there is further reason to expect the planned enterprise to disturb the environment more than a capitalist from in a similar situation.

This conclusion is further strengthened if we admit the possibility of harassing legal action against the capitalist firm. The contrast is now between a planned economy in which production is efficient, given a vector of socially imposed shadow prices (and hence in which welfare is maximized), save for the inclusion of environmental damage costs, with a market economy in which a competitive firm ignores the environmental impact of its actions except to the extent that it provokes suits from environmentalists (conceivably including the government). While it is true that polluters do not entirely avoid legal action from injured parties in the USSR, it is apparent that such action is far more common in market economies.[88]

The logic for this tendency is apparent: well defined property rights tend to make welfare losses accrue relatively more to private agents than to socially owned factors in market economies. There is a natural reluctance for one arm of the government to sue another, particularly if nearly all agents are contributing to environmental deterioration in some manner. Moreover

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[87] If $\varepsilon<-1$, then a 1% fall in production would result in a price rise in excess of 1% ; since revenues would therefore rise while input costs would fall, a profit-maximizing monopolist would never locate at such a point.

[88] The magnitude of such fines is generally small, though, and often contribute to the discretionary revenue of local public bodies (K.Bush [6], p. 19). The fines may also be viewed by the firm as being an inevitable lump sum fee necessary to maintain good community relations. Bush also points out (p. 23) that Soviet environmental legislation typically lacks the precision of western laws. An extensive discussion of environmental law enforcement in practice is given in T. Gustafson [20].

individual victims of pollution cannot take direct legal action in the Soviet Union, but can only file a complaint with the relevant environmental protection authority.[89] On the other hand, private firms and individuals in capitalist countries who suffer property damage are comparatively free to seek legal remedies, particularly if the offender is an easily identified private firm. Nor does environmental protection in the USSR benefit from the presence of powerful government allies with a function completely separate from those agencies involved in natural resource exploitation.[90]

Finally, while pollution fines are limited in the USSR, the Soviet pricing scheme may reduce their impact further. As Fel'zenbaum ([9], pp. 30-31) points out, any fine that the firm manages to have included among its operational costs is deflected to the extent that output prices are adjusted upwards by the planners. The lack of price responsiveness further along the product chain limits even the long run impact of any fine on the polluting firm.

Returning to the analysis of the lawsuit, assume further that the expected cost from being sued (the probability of a suit times the expected legal costs and cleanup costs) rises with E. Then it is easy to show that if the firm maximizes expected profits, the more possibility of a suit will lead to lower levels of environmental disruption. The reaction of environmentalists effectively changes the "price" of disturbing the environment from zero to a positive value, since the larger is E, the greater are the firm's expected litigation costs. Even if the firm has complete confidence that it will ultimately prevail in court, anticipated legal costs and temporary injunctions will still have a modifying impact on its environmental behavior.

Let us now turn from the comparison of profit maximizing entrepreneurs with efficient planners to an examination of the behavior of less profit-oriented management. Many large polluters in capitalist countries are subject to detailed public regulation concerning the prices they may charge and the inputs they choose. In particular, western nations at roughly the Soviet Union's level of development are likely to be interested in maintaining high levels of employment in the relatively productive manufacturing sector. The employment level in such a firm may exceed the profit maximizing level if employment and other firm decisions are reached by agreements between the firm and government.

As long as firms try to maximize profits in choosing the level of E, any level of L in excess of the competitive level will have deleterious effects on environmental quality. This result can be seen from maximizing profits (1) with respect to E, and expressing the optimal E that results as a function of L:

$$E^* = \left(\frac{e}{bd}\right)^{\frac{1}{d-e}} L^{\frac{\ell}{d-e}} , \qquad (6)$$

which implies $dE^*/dL>0$, as $d>e$. The problem of maximizing profits subject to fixed employment levels could be confronted conceivably either by a western manager, or the director of a Soviet firm. In either case, the level of environmental disturbance will exceed the competitive level.

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[89] See D. Kelley, et al. [25], pp. 172-173.

[90] K. Bush ([6], p. 22); also see D. Kelley [26] and especially T. Gustafson ([19] and [20]) for discussions of environmental authorities. However, in 1974 a special environmental division was set up within Gosplan, while the Hydrometeorological services also monitors water quality along with the Ministry of Water and Land Reclamation.

A more realistic model of managerial behavior that is applicable both to large capitalist firms and large socialist enterprises is given by the "bureaucracy theory" models of Niskanen and others.[91] In a capitalist environment, it is posited that a manager's salary perquisites are directly related to a firm's sales. Consequently, especially in a highly regulated environment, the manager of a large private or public enterprise will seek to maximize output subject to a zero (or other fixed) profit constraint. This maximand also may be a fairly realistic one for a Soviet manager. Indeed, the Soviet manager until recently was urged explicitly to maximize output given the levels of some non-environmental inputs and implicit limits on profits. As experiments with profit-related objectives have grown, the appropriate maximand may have moved closed to the efficiency criteria assumed above (given prices that are not generally socially optimal, though). The high degree of control over input use undoubtedly blurs the distinction among maximands at the firm level as well. Output oriented goals remain important, though, and are especially dominant at the ministerial level.

In the output maximization case, the environment once again suffers more than it would under competitive, profit maximizing behavior. If profits (revenue less labor costs) are positive at the competitive output level, then by assumption the manager will use the proceeds to hire additional labor; with the additional labor the manager will also find it desirable to increase the level of environmental disruption. In terms of the standard cost curve diagrams, equilibrium now occurs where average cost (rather than marginal cost) equals price, leading to higher output and input levels. To the extent that the output maximizing model is more appropriate for the Soviet manager or his ministerial supervisors than for his western counterpart, it is again apparent that E will be higher in a Soviet firm than in a comparable private firm.

It should be recognized that these results do not depend on a restriction of the number of non-environmental inputs. For example, suppose that output depended on capital, K, as well as E and L:

$$Q = L^{\ell}E^{e}K^{h} - bE^{d}. \tag{7}$$

Then profit maximization yields

$$E^{*} = \left(\frac{e}{bd}\right)^{\frac{1}{d-e}} K^{\frac{h}{d-e}} L^{\frac{\ell}{d-e}} \tag{8}$$

Defining r to be the unit cost of capital, obtaining similar expressions for K and L, and then solving for E as a function of input and output prices yields

$$E^{*} = P^{c(h+\ell)} \left(\frac{\ell}{w}\right)^{c\ell} \left(\frac{h}{r}\right)^{ch} \left(\frac{e}{bd}\right)^{c(1-\ell-h)} \tag{9}$$

where $c = [(d-e)(1-\ell-h) - e(1-h\ell)(\ell+h - 2\ell h)(1-h)^{-1}(1-\ell)^{-1}]^{-1}$ is a constant that will be positive for reasonable parameter values. From (8) and (9) one finds $dE^*/dK>0$, $dE^*/dL>0$, $dE^*/dP>0$, $dE^*/dw<0$ and $dE^*/dr<0$.

[91] See W. Niskanen [39] and W. Oates and D. Strassmann [41].

Consideration of capital inputs strengthens the results obtained earlier. Capital provided to a firm in excess of the competitive optimum will generate a larger E. Furthermore, even if capital inputs are not provided in excess, the fact that capital is provided freely will enable the output-maximizing Soviet manager to produce more than the comparable capitalist manager, leading to a greater environmental disturbance. Of course, this result will be offset to the extent the Soviet manager faces artificially high wage costs or low output prices.

A final maximand for the Soviet manager that deserves comment involves the maximization of output growth over a five-year period, subject to a zero profit constraint. Even if E is a depletable good (that is, environmental damage is not cumulative), the growth-maximizing manager will be very conservative-minded in the early years of the plan, using a portion of his labor force to offset the dislocating activities of the "productive" factors. These clean-up projects may be particularly large if the manager takes non-environmental inputs as given. Toward the end of the FYP, though, conservation programs will be abandoned as the manager concentrates on production.

The pattern of environmental destruction may thereby to some degree follow a cyclical pattern. This is particularly true to the extent that there exist some incentives for environmental preservation. A firm may find it desirable to demonstrate its compliance with effluent discharge standards in the early stage of an FYP while intending to commit large violations later. Since the Ministry of Water and Land Reclamation inspectors would be most unlikely to take immediate action, even if caught the firm would be safe for the duration of the FYP (and its output-for-the-sake-of-the-Plan excuse would receive a favorable hearing). With luck, the firm might even receive an allocation in the next plan for environmental equipment; given the equipment shortages and construction delays, part of this allocation could be shifted to inputs that would ensure rapid output growth in that plan.

Concern with growth over an intermediate period may also generate environmental disturbances of a qualitatively different sort than in Western nations. The goal of achieving high output growth rates will lead a manager to employ small or zero discount rates for future output. By contrast, the private manager is likely to employ a discount rate well above the social discount rate, in view of capital taxes. Consequently, environmental disturbances resulting from production activity that generate few costs now but have the potential to hamper future production will be avoided more by the Soviet firm with fixed location than by his western counterpart. More generally, Soviet firms should be more careful than western firms in creating environmental dislocation with cumulative, irreversible effects.

Given the highly cumulative effects of the withdrawal of water from rivers that flow into the southern Soviet seas, the conclusion above appears somewhat surprising. In these cases, though, the cumulative damage is not borne by those who withdraw the water upstream, but by those who live further south. In other words, it is the cumulative nature of damage to the production capacity of the firm in question that matters.

In summary, models of managerial behavior suggest that a Soviet firms' environmental disturbance is likely to be greater than that of a comparable western firm. This outcome is particularly likely in the event that the western firm exercises market power and responds to fears of lawsuits. It is also particularly likely if the Soviet firm maximizes profits given low shadow costs of capital or labor, or if the Soviet firm maximizes output subject to a zero profit constraint and faces low stated input costs. The greater pollution outcome is less likely if the western firm is also run by an output-maximizing manager. The outcome is also less likely if the environmental effects in question have strong cumulative effects on the firm and the firm's decision-maker is interested in maximizing output growth.

These conclusions suggest that under many circumstances, a Soviet firm will create more environmental degradation than a comparable western firm. Essential to the conclusions is the assumption that firm decision-makers ignore the social costs of their polluting activity. If Soviet firms are more conscious of their environmental effects and are more socially responsible than their western counterparts, then the maximands discussed above require revision, and Soviet firms may pollute less.[92] It is important to recognize, though, that there are few reasons other than social consciousness to expect the Soviet firm to be a smaller polluter. Unfortunately, the Soviet planning system appears to greatly restrict the instances in which environmental consciousness is an important factor in firm behavior.[93]

5. ENVIRONMENTAL DISTURBANCE AT A NATIONAL LEVEL

The previous section indicated that Soviet firms were likely to create more environmental damage than comparable Western firms, unless concern for the environment were substantially greater. It is necessary to consider whether these results will be sustained at a macroeconomic level.

At an economy-wide level, mobile resources not employed in one industry will seek employment elsewhere. Thus, the monopolistic firm that keeps its output and labor force below competitive levels and hence pollutes will not be a source of reduced aggregate environmental damage if the workers not employed at the monopolistic plant (as compared with a competitive one) generate even greater pollution in other occupations. Conversely, excessive employment by a social planner or output-maximizing bureaucrat may reduce aggregate pollution if their employment keeps employment low in even more polluting sectors.

A notable characteristic of the Soviet economy is its relatively low share of the labor force in the service sectors. Although the share of the total labor force employed in services rose from 29% in 1960 to 41% in 1980, this latter level is still lower than that for any of the industrial market economies.[94] Insofar as service workers contribute less than industrial or agricultural workers to water pollution and water use, Soviet industrial employment creation that draws workers from services in aggregate will have a negative environmental impact. That is, Soviet policy at macro and micro levels has resulted in a large industrial and in a small service sector as compared with comparable market economies. It appears safe to conclude, then, that workers have been pulled into relatively high polluting industrial activities as a result of the incentive structure in large Soviet firms.

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[92] Soviet managers also face the problem of degermining which objectives indicated by the leadership are to take priority. As L. Taga [59] notes, thé "ideal preferences" of the leadership may differ considerably from perceptions of their "effective preferences". Taga also addresses several problems confronting the USSR in dealing with environmental problems not analyzed here, including planning inconsistency, structure of authority relationships in the Soviet Union (ministerial departmentalism), and the failure of actual prices to reflect social value. These problems serve to hinder the emergence of a "socially conscious" Soviet manager that chooses to value the environment in his maximand in place of maximands assumed above. Taga also provides a detailed description of the incentive structure facing managers.

[93] See C. Zeigler [71], L. Taga [59], and, for a different perspective, J. McIntyre and J. Thornton [33].

[94] The World Bank [66], p. 189.

Soviet agriculture is also likely to be water-intensive relative to a comparable capitalist agricultural sector. If Q is viewed as a fixed target level of agricultural output in (7), it is apparent that (as long as $\partial Q/\partial E>0$) the value of E required to meet the target will vary inversely with L^{ℓ} and K^{L}. Poor labor productivity incentives characteristic of Soviet agriculture thereby imply a low value of L, requiring large doses of capital and irrigation water to compensate.

In summary, it is possible that the higher levels of E at the firm level need not imply greater aggregate environmental disruption with Soviet incentives in place of capitalist ones. The types of industrial goods and personal services provided may vary systematically from one economy to another, and the "western type" may be more environment-intensive. Acute fresh water shortages in the southern USSR may also provoke a reasonable degree of voluntary environmentally-conscious behavior by Soviet managers and ministries. In the absence of such information, it seems likely that the Soviet industrial firm's production decisions do have a net polluting effect, and that these effects are augmented by a needlessly water-intensive agricultural system. Yet the severity of the fresh water constraint to economic growth in the southern USSR may well serve to offset the negative environmental effects of the Soviet incentive system. It appears characteristic of a system not highly motivated by efficiency concerns that the Soviet response to the scarcity problem has been to plan huge water diversion schemes and massive centralized pollution control projects, but not to alter substantially basic water use incentives.

As disposable incomes rise in the USSR, the demand for environmental recreational amenities can be expected to grow rapidly. The vastness of the Soviet Union will permit much industrial expansion before the supply of recreation sites is pressed. Demand for year-round amenities such as clean water and local recreation sites will also grow rapidly; at least in the latter case, though, costs of providing the sites may well rise more rapidly (at least as perceived by the planner). The future will depend largely on whether or not the rate of response to this demand and the amenity demand growth are sufficient to offset increasing damage associated with further growth.

Thus far, environmental protection in the USSR typically has lacked strong enforcement mechanisms. Rising demand for fresh water inputs into industrial and agricultural production in the southern USSR and for water-using recreational facilities everywhere may result in discrete institutional changes in water resource protection that lead to different managerial behavior than that posited here. Fining the manager of a polluting plant 50 rubles or withholding a bonus due to a violation will not build the necessary water pollution control facilities. Unfortunately, changes in rules may well substantially precede changes in power and funding. Gosplan's Division for the Protection of Nature does not appear to have ministerial clout remotely resembling the U.S. Environmental Protection Agency. Uncoordinated actions with environmental effects continue to result from the "departmentalist" nature of the Soviet economy, with many decisions effectively made by distant officials unconcerned with any spillover effects that result. These problems, however, have led to a push to balance the departmentalist ministerial structure with more powerful regional planning (see Feitel'man and Smagarinskii [8]).

Even while the resource commitment for a national water purification plant construction program is substantial, current problems are severe. Many obsolete water treatment systems need to be scrapped, ideally in favor of new, technologically advanced closed-system and effluent-reduced systems. Soviet studies also indicate that waste treatment and water purification plants are usually built by non-specialized local construction organizations.[95] Essentially, general contractors attempt to built rather complicated systems without always having the technical know-how or proper tools. Further, it is standard procedure to build water treatment plants of whatever sort last as opposed to erecting them concurrently with the industrial enterprise. Unsurprisingly, the above procedures often result in poor quality plants.[96] Insufficient production of mechanical aerators, scroll centifuges, special sewage pumps, turboblowers and other needed equipment is considered to be an "acute problem" (see K. Sharonov [54]). Although a labor shortage exists for qualified personnel to design, contract, and operate the plants, as of 1979 no university in the Soviet Union offered a specialized training program for urban sanitation encompassing the processing of domestic solid waste.[97] In brief, major changes in the currently tepid pace of water treatment plant construction hardly appear to be imminent.

If it is difficult to be optimistic regarding water treatment facilities, it is equally hard to envision a transformation of Soviet agriculture. Energy has been concentrated on an agricultural program that puts a premium on rapid expansion and the cultivation of hitherto virgin soil. The land expansion has come in semi-arid areas, though, that might have been found to be inefficient if productivity in traditional areas had been higher. With half of all Soviet water use devoted to irrigation, some conservation measures in agriculture must offer high returns. Indeed, agricultural rationalization might well involve the abandonment of many areas (even ignoring water use considerations). The political institutions seem much more likely, though, to instigate massive water diversion schemes than radical water conservation projects or agricultural incentive reforms.

Dealing with problems such as "acid rain" appears even more remote. Yet a determined effort by a Soviet-style "command" economy to reform environmental policy would be likely to generate results far more rapidly than in a decentralized, pluralistic society as long as the reforms are imposed from the top. So far, the need for water has generated massive construction programs and environmental awareness has resulted in the strengthening of laws and conservation agencies, but it has not challenged seriously the powerful industrial ministries or led to major agricultural policy changes. Future events depend largely then on whether or not the senior Soviet leadership expresses a firm extra-legal commitment to water resource preservation in addition to investments needed to offset current inefficiencies in water resource use.

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[95] Izvestiia [24], p. 24.

[96] A recent tour of facilities in Saratov Province revealed that half of the waste treatment plants were operating inefficiently and that major effluent discharge violations had resulted due to their poor operating condition. See A. Vorotnikov [65], p. 25.

[97] Raznoshchik and V. Lubov [49].

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