HUMAN DIMENSIONS OF ECOSYSTEM ANALYSIS IN CENTRAL ARIZONA: AN OVERVIEW

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INTRODUCTION

This background report on human-environment feedbacks describes many of the ways humans have altered, and are continuing to affect, the physical environment. It also examines the ways the changed environment is in turn affecting humans. This report does not go into much depth on any particular topic, but instead attempts to identify the many issues. It discusses the drivers of human elements in the ecosystem in somewhat more detail, using the framework defined by Redman.

While in some ways a generalized discussion, it is specific to Central Arizona to the extent possible. The remainder of this introduction consists of the identification of environmental issues in the arid Southwest and of the public's perceptions of such issues in Arizona.

Environmental Issues

Several assessments of environmental issues have been made for Arizona and the surrounding region. Each is defined somewhat differently: threats to biodiversity, anthropogenic stresses, and the importance of, and risk associated with, environmental issues.

According to Nabhan and Holdsworth, all of the top threats to biodiversity in the Sonoran bioregion (Arizona, Baja California Norte and Sonora) relate to human activities, with the top two threats simply population growth and urbanization:

"1. Urbanization's aggravation of habitat conversion and fragmentation;
2. The high rate of in-migration of newcomers to reside, work and recreate in the region, and their contribution to population growth and resource consumption;
3. Surface water impoundment and diversion from places where native vegetation and wildlife have access to it;
4. Inappropriate grazing of vegetation by livestock, especially when combined with conversion of plant cover to exotic pasture grasses;
5. Aquifer mining and salinization, the drop in the water table, and their long-term effects on riparian vegetation and wildlife;
6. Lack of planning for growth;
7. Exotic grass planting;
8. Conversion to farmlands;
9. Recreational impacts;
10. Biological invasions."

This ranking was developed from the input of scientists with substantial field experience in the Sonoran region.

The Environmental Monitoring and Assessment Program of the U.S. Environmental Protection Agency (EPA) has identified several major anthropogenic (human-engineered) stresses in arid lands: loss of riparian habitat, overgrazing, introduction of exotic species, increased fire frequency, effects of global climate change, and decreased water supplies.

The Arizona Comparative Environmental Risk Project (ACERP) identified and rated the importance of 14 issues:

Very High:	Outdoor air quality
High:	Groundwater contamination
	Physical alterations of ecosystems
	Degradation of built and cultural environments
Medium:	Biological alteration of ecosystems
	Food and water contamination
	Indoor air quality
	Land and soil contamination
	Surface water contamination
Low:	Workplace/consumer exposure to hazardous materials
	Global climate change and ozone depletion
	Accidental releases
	Natural hazards
	Radiation

A combination of science and politics, ACERP developed a baseline of the best scientific data on the environmental risks facing Arizona, and incorporated public perceptions and values regarding the relative importance of the risks.

Public Values and Perceptions on the Environment

As part of ACERP, a survey of the public was conducted in 1995. Two-thirds of those contacted responded "climate" when asked "what do you like most about living in Arizona," with 11 percent answering "deserts, mountains, natural areas."

In terms of level of concern, "environmental quality" ranked third behind "crime" and "education," just ahead of "jobs and taxes." Nearly two-thirds of the respondents showed great concern for the environment, with the percentage higher among females, lower-income households, and young adults. Older high-income residents, who generally hold power in the community, were less distressed, though one-half were greatly concerned with environmental quality.

Another 1995 survey, conducted by the Tribune Newspapers, found that Valley residents thought it more important to "maintain the desert and mountain scenery" and to "maintain high air-quality standards" than to "spend more tax money on police protection" or to "spend more on public education."

However, a 1998 survey conducted by the Morrison Institute for Public Policy at Arizona State University as part of its annual quality-of-life report indicated that the environment was in the second tier among "what matters most in Greater Phoenix's regional quality of life." "Education" received one-fourth of the votes, with "families and youth" and "public safety/crime" each garnering about one-fifth. "Health and health care," the "environment" and the "economy" each received from 6 to 8 percent of the votes, while few indicated "community," "transportation," and "arts, culture and recreation" to be what matters most.

The local environment was believed to be good for health by a little more than one-third of the ACERP respondents, with nearly as many thinking it to be bad for health. The proportion selecting "good for health" ranged from 70 percent in rural areas to 30 percent in suburbs and 24 percent in cities. One-half thought the environment had not changed in the last five years, while one-third said that it had gotten worse for health.

In general, rural residents were less concerned than urban dwellers about a list of 20 specific environmental issues, such as drinking water quality and air pollution. On most issues, females expressed more concern than males.

Economy v. Environment

Nearly 75 percent of those surveyed by ACERP said that economic growth and environmental protection should occur at the same time. Approximately 20 percent favored the environment over the economy, while only 6 percent said that economic growth should be given priority. Nearly 75 percent thought that a thriving economy could not exist without environmental protection. More than 75 percent did not agree that the purpose of plants and animals is to serve humans and that those species that are not helpful do not need to be protected.

Nearly 50 percent said that economic growth was overemphasized by government to the detriment of the environment. Only 15 percent thought that the environment was accentuated at the expense of the economy.

Seventy percent or more agreed with each of three statements: the environment is an interconnected whole, the environment should be protected even if some jobs are lost, and the environment should be preserved for future generations even if it means lowering today's standard of living. However, nearly two-thirds indicated that their first duty was providing for their family, with the environment coming after that

Summary

In sharp contrast to the top threats identified by Nabhan and Holdsworth, surveys of urban dwellers in Arizona show relatively little concern for population growth even though it aggravates nearly all of the problems for which the public is more troubled, such as water quality and landfills. Similarly, the popularity of new housing areas at or beyond the urban fringe and the very high percentage of citizens who commute to work alone, often long distances, suggests that residents have relatively little concern for vehicle miles traveled (VMT). However, VMT is a key factor in the Valley’s air quality for which residents express considerable disquietude.

Thus, while residents of Central Arizona have significant concern for the environment, they seem unwilling to accept responsibility for the negative effects their actions have on the natural ecosystem. Further, since the record of Arizona politicians has reflected less concern for the environment than expressed by citizens in polls, either concerned residents are not civically active or many vote for politicians that do not share their environmental views. Most significantly, many residents do not understand, or are reluctant to acknowledge, that human population growth presents the major stress to the health of the natural ecosystem in Central Arizona.

ENVIRONMENTAL CONDITIONS ENABLING HUMAN DEVELOPMENT

Availability of water and arable land were the most important factors enabling the early settlement of Central Arizona. As the region transformed from agricultural to urban uses in recent decades, water remained important, but arable land was supplanted by easily developable, and therefore inexpensive, land as a significant factor. Climate, landforms, scenic attractions and unusual ecosystems all play important roles in the area's rapid human population growth.

Required or Highly Desirable Conditions

In order for humans to make more than occasional, non-intensive use of an area, the local ecosystem must possess certain attributes. The most important of these is the availability of water.

Native Americans

Year-round running water in the Verde, Salt and Gila rivers allowed the first humans to settle several thousand years ago in what was to become the Phoenix area. As hunters and gatherers, these peoples were few in number and had relatively little impact on the environment, though they may have contributed to the extinction of several large mammal species.

For more permanent and dense settlement by humans, arable land was necessary. (Today, because of the ability to import foodstuffs, arable land is desirable rather than necessary.) The river valleys of Central Arizona had an abundance of cultivatable land. Thus, as the aboriginal settlers adopted farming, mostly in floodplains, the human population of Central Arizona rose and the first significant impacts on the ecosystem occurred.

During the Hohokam period of canal building, more land was cleared for farming, allowing human population numbers to further rise. Widespread clearing of the land marked the first major land use change in Central Arizona. Because water was transported to the fields from surface water at some distance, irrigation caused the water table to rise in some places, modifying the flora and fauna beyond the cleared land.

Europeans

Europeans settling in Central Arizona revived irrigated farming around 1868, initially producing ecosystem effects similar to those of their predecessors. Rather quickly, however, the utilization of the land intensified greatly. The creation of dams, reservoirs and extensive canals produced more widespread impacts on the environment and allowed more humans to live in the Phoenix area. Each major dam in Central Arizona was completed between 1911 and 1945. Groundwater pumping increased steadily from the early 1900s into the 1950s. These two developments resulted in an increase in land transformation to farming and produced other ecosystem impacts. For example, in those areas subject to pumping the water table began to lower.

When the population of the Phoenix area began to increase rapidly after World War II, developable land at a reasonable cost became a highly desired feature. An abundance of flat land in the Phoenix area enabled its urbanization. While part of the urbanization occurred on farmland, much of it transformed the natural habitat (discussed in more detail in Land Use and Change, page 14). Urbanization increased the number and severity of impacts to the ecosystem over and above those caused by farming and ranching.

Amenities

A variety of quality-of-life factors enhance human development in any region. In the Phoenix area, climate has been a strong amenity since the days of aboriginal settlement. The length of the growing season and the ability to have two growing seasons in a year were strong advantages to farming in Central Arizona. Climate continues to be a positive factor for agriculture in the Phoenix area, not only because of its influence on growing seasons, but also because of the ability to grow products, such as citrus, that cannot be grown in most of the country or world. In addition, climate contributes to the high yields realized for many crops in Central Arizona.

In recent decades, climate as an amenity has been a key factor in the rapid population growth of the Phoenix area, attracting new residents from among those living in colder, wetter climates. The area's landforms, scenic attractions and unusual ecosystems also have played a role in attracting newcomers.

These quality-of-life factors have influenced the area's economic structure, being key elements supporting large tourism, retirement and winter visitor industries. The same factors contribute to the growth of other industries, at least indirectly, by making it easy for employers to attract a labor force willing to work at relatively low wages.

Other factors than quality of life also are important to human development. For example, the Phoenix area stands out for its low incidence of natural hazards. However, the Phoenix area is largely deficient in natural resources such as minerals or energy. Thus, most of the materials used in construction are imported from some distance. An important exception is sand and gravel, mined primarily out of the Salt River bed.

HUMAN DRIVERS OF THE ECOSYSTEM

The rapid growth of the human population in Central Arizona has had widespread effects on the natural ecosystem. The sheer increase in number of residents and visitors is the primary human driver of the ecosystem. The key underlying factors behind this growth are the natural ecosystem's attributes, particularly its climate.

Initially, agriculture (farming and ranching) was the primary stimulus to human settlement in Central Arizona. Thus, in the early 1900s, the Phoenix area economy was highly tied to agriculture. After World War II, the structure of Maricopa County's economy shifted substantially, most notably with a relative gain in manufacturing and loss in agriculture. This triggered the rapid urbanization that continues today.

The process of urbanization was propelled by pro-growth attitudes developed by local business leaders. Originally led by a relative few, the business power base broadened with time, firmly establishing the actively pro-growth philosophy that continues today in both the private and public sectors of the Phoenix area.

Beyond growth itself, the nature of the urbanization has had additional impacts on the natural ecosystem. With almost all of the growth occurring in the automobile-oriented post-World War II era, the population density of the area always was low, resulting in a disproportionately large amount of land being transformed. Planning was limited, a result of the traditional independent, anti-government spirit of the West. The prevalence of this mind-set continues to attract a disproportionate share of like-minded migrants.

Demographic Patterns

Historical

The population of Maricopa County in 1900 was only 20,000; it will be near 3 million in 2000. Almost two-thirds of this nearly 3 million increase occurred in the last 30 years of the century. Only 6 percent happened in the first 40 years of the century even though the population multiplied nine times.

As seen in Table 1, numeric population growth in Maricopa County generally accelerated throughout the 20th century. (Some of the rapid growth shown for individual cities resulted from annexations of already settled areas.) Annual population gains accelerated from only a few thousand to more than 80,000 in the mid-to-late 1990s. The county did not reach a population of 700,000 until 1961, but added the next 700,000 in only 18 years. The pace further accelerated, with the population rising from 1.4 to 2.1 million in 10 years, then to 2.8 million in nine years (in 1998).

Maricopa County is home to nearly 60 percent of the state's residents, a share that has grown throughout the century from only 17 percent in 1900. In the latter part of the century, about two-thirds of the people migrating to the state moved to Maricopa County.

In recent decades, approximately two-thirds of Maricopa County's population gain has resulted from net in-migration (see Table 2). In the mid-to-late 1990s, about 170,000 people per year moved to Maricopa County, but 110,000 left the area, resulting in annual average net in-migration of 60,000. Thus, even in rapidly growing Central Arizona, many people leave, frequently after having been residents only a short time.

This net inflow represents a huge flow of inputs into the area. It makes planning more difficult, offsets progress made in reducing pollution, and creates similar complications to resolving almost all issues in Central Arizona.

TABLE 1
POPULATION IN THOUSANDS
Selected Jurisdictions in Maricopa County

	County	Urban Area	Phoenix	Mesa	Glendale	Scottsdale	Tempe	Chandler	Peoria	Gilbert	Rest of County
1900	20	N/A	6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	14
1910	34	N/A	11	2	N/A	N/A	1	N/A	N/A	N/A	20
1920	90	N/A	29	3	3	N/A	2	N/A	N/A	N/A	53
1930	151	N/A	48	4	4	N/A	3	1	N/A	1	90
1940	186	N/A	65	7	5	N/A	3	1	N/A	1	104
1950	332	216	107	17	8	2	8	4	N/A	1	185
1960	664	552	439	34	16	10	25	10	3	2	125
1970	971	863	584	63	36	68	64	14	5	2	135
1980	1,509	1,409	790	153	97	89	107	30	12	6	225
1990	2,122	2,006	983	288	148	130	142	91	51	29	260
1998	2,806	N/A	1,221	362	197	195	159	160	90	91	331

NUMERIC CHANGE

‘00-10	14	N/A	5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	9
‘10-20	56	N/A	18	1	N/A	N/A	1	N/A	N/A	N/A	33
‘20-30	61	N/A	19	1	1	N/A	1	N/A	N/A	N/A	37
‘30-40	35	N/A	17	3	1	N/A	0	0	N/A	0	14
‘40-50	146	N/A	42	10	3	N/A	5	3	N/A	0	81
‘50-60	332	336	332	17	8	8	17	6	N/A	1	-60
‘60-70	307	311	145	29	20	58	39	4	2	0	10
‘70-80	538	546	206	90	61	21	43	16	7	4	90
‘80-90	613	597	193	135	51	41	35	61	39	23	35
‘90-98	684	N/A	238	74	49	65	17	69	39	62	71

Source: U.S. Bureau of the Census, decennial census counts, 1900-90, and Arizona Department of Economic Security, 1998 estimates.

Migrants

The most numerous migrants to Central Arizona are young adults and most are part of the labor force. Employment is the most important force pulling migrants to the Phoenix area, but the climate has a significant secondary role. Net in-migration is highly cyclical since job creation varies substantially over economic cycles, which are more extreme in the Phoenix area than the national average.

Many young migrants to Central Arizona subsequently leave the area. This impermanence combined with preoccupation on work and starting a family means that many of these migrants do not take an active role in the community. More generally, high mobility and the relatively recent growth of the area has resulted in few natives or long-time residents of the Phoenix area.

Related to their youth, the typical migrant's income has been below the Phoenix area median. These moderate incomes and the desire to live in singe-family homes have contributed to the destruction of the native habitat, by increasing the demand for inexpensive housing on small lots. Such subdivisions usually have been created on land denuded of all vegetation. In recent years, the substantial size of the baby-boom generation has shifted migration flows toward middle age. The result has been more large, expensive homes, and fewer starter homes, being built.

Retirement-age migrants to Central Arizona are much less numerous than younger adults. However, few of these older migrants subsequently move from Central Arizona, thus net migration in this age group is fairly large. Even with their net in-migration, the proportion of the population of retirement age is less in the Phoenix area than the national average. Since so many of the older migrants settle in age-restricted communities, their presence is more noticeable in the Phoenix area than in most places.

Most migrants to Central Arizona come from other U.S. states rather than from other countries. In particular, many move to Central Arizona from other western states. However, many of these newcomers originally lived east of the Rocky Mountains, in particular in the northern Plains and Great Lakes regions. In the past, a higher proportion of the migrants to the Phoenix area came directly from these regions.

TABLE 2
POPULATION CHANGE IN MARICOPA COUNTY
Annual Average in Thousands, By Economic Cycle

Economic	Total	Net Migration		Births-		
Cycle	Change	Number	% *	Deaths	Births	Deaths
1961-70	30	19	63	11	18	7
1971-75	55	44	78	11	20	9
1976-82	54	41	76	13	24	11
1983-91	66	45	68	21	36	15
1992-98	81	56	69	24	43	19

* As a percentage of total population change.

Source: Center for Business Research, L. William Seidman Research Institute, College of Business, Arizona State University.

According to Nabhan and Holdsworth, "the present inhabitants' unfamiliarity with desert land and water management poses profound threats for most land, water, vegetation and wildlife resources within a half-hour's drive of the region's largest metropolitan areas." For example, rather than adapting to the natural habitat, most newcomers have wanted to create an oasis filled with tropical plants or species with which they were familiar in their moister and cooler previous residences. This has led to high water use and the introduction of many exotic species in Central Arizona.

Projections

Rapid population growth in Maricopa County is expected to continue over the next 50 years. The 2000 population of nearly 3 million is projected to swell to more than 7 million in 2050. Annual growth in the next two decades is expected to slow somewhat from the pace of the 1990s, but gains after that should gradually rise (see Table 3). The current 83,000 per year average population change is projected to rise to 100,000 around 2050.

Over the next 25 years, the Maricopa Association of Governments predicts that development will shift somewhat from the southeast part of the Phoenix area to the north and southwest. The population center of the county has shifted to the east over the last 20 years, to northeast of Thomas and 24th Streets in 1995. Over the next 25 years, it is projected to move slightly west and north.

A small portion of Pinal County (Apache Junction) already is included in the Phoenix urbanized area. More of Pinal County will be added to the urbanized area over time. Pinal County's population is projected to rise from 158,000 in 1998 to 231,000 in 2020.

Public Perceptions on Growth

Perceptions on population growth seem to vary. In the 1998 Morrison Institute survey, more than three-fourths of the respondents thought that population growth in the Phoenix area was too fast; only 1 percent thought it was too slow. In the 1995 ACERP survey, less than 40 percent of urban residents expressed great concern about population growth, compared to 57 percent of rural residents. Young people expressed less concern than older adults. Overall, population growth ranked 14th among 20 issues in level of environmental concern. Drinking water quality, disposal of hazardous wastes, air quality and the condition of natural areas were rated to be of most importance.

TABLE 3
MARICOPA COUNTY POPULATION PROJECTIONS IN THOUSANDS

	Population	10-Year Change
2000	2,954	832
2010	3,710	756
2020	4,516	806
2030	5,391	875
2040	6,296	905
2050	7,265	969

Source: Arizona Department of Economic Security.

This relatively low interest in population growth among urban residents stands in stark contrast to the opinions of field scientists compiled by Nabhan and Holdsworth. It also is inconsistent in that most of the issues rated by urban residents to be of greater concern than population growth are adversely affected by that growth.

Economic Systems

Since the 1950s, Central Arizona has been a favored spot for the relocation of individuals and families, largely because of its climate but also because of other perceived advantages. The ease with which a work force could be drawn to the area at reasonable cost, and other low costs of doing business, influenced employers in their expansion and relocation decisions. In turn, the availability of jobs made the area even more favored by workers.

In the long-term, the two forces act together to keep the Phoenix area's growth rate high. In the short-term, however, the availability of jobs controls the migration of people. Despite the area's industrial composition being similar to the national average, economic cycles tend to be more severe in Phoenix. The relatively large size of construction, the most cyclical of industries, contributes to this variability.

Thus, population growth goes up and down with the economic cycle. However, only in the worst recessionary years does the Phoenix area not produce more jobs than can be filled by the resident population.

Historical

Prior to World War II, the Arizona economy was known by the "four Cs" of copper, cattle, cotton and citrus. In Central Arizona, mining never was a significant economic activity. During this period, Arizona's industrial mix was considerably different from the national average. Some historians add a fifth C of climate, representing tourism, but tourism was not of particular importance until after World War II.

The federal government provided the first stimulus to more rapid growth and urbanization of Central Arizona in the early 1940s. A goal of linking the large population centers of the East Coast to those on the West Coast led to construction of roads, airports and other infrastructure. In addition, military installations were built. Construction became an important industry and population growth accelerated: after rising 166,000 in the previous 40 years, Maricopa County's population rose 146,000 between 1940 and 1950.

Despite this early urbanization, the Phoenix area economy largely remained agrarian into the early 1950s. Thus, until about 45 years ago, the major human impacts on the Central Arizona ecosystem came from agriculture — ranching and farming — not from urbanization.

After this, the Phoenix area rapidly transformed to an urban economy. Tourism increased and the manufacturing industry expanded vigorously. The relative importance of agriculture declined: its share of county employment dropped from 17 percent in 1950 to 9 percent in 1960. These changes represented convergence toward the national economic structure.

Manufacturing

The creation of manufacturing and other urban jobs enabled the population of the Phoenix area to grow rapidly. While many people from around the country became familiar with the region during World War II, and the spread of air conditioning made dwelling in the desert more attractive, the potential for growth was limited as long as the economy was based on agriculture.

Some of the large firms establishing operations in the Phoenix area were Motorola, General

Electric, Goodyear Aircraft, Kaiser Aircraft Electric and Sperry. In particular, three manufacturing sectors grew substantially. The aircraft sector experienced sharp expansion in the early 1950s. The electronics sector (mostly communications equipment) began in the Phoenix area in the mid-1950s, with rapid expansion starting in the late 1950s. The industrial machinery sector expanded moderately throughout the decade. These economic activities resulted in environmental damage that still has not been remediated, such as soil and water contamination in the Superfund site in Scottsdale.

Agriculture

By the late 1960s, Maricopa County's industrial mix, relative to the national average, was not much different from that of the current time. Agriculture's sectoral share of industry earnings was down to only 3 percent.

Corresponding to agriculture's declining share of economic activity, the amount of land used for agricultural purposes dropped considerably. From the peak in 1954, total agricultural acreage dropped 74 percent by 1997. The decline in cropland was 41 percent, while land acreage used for grazing fell 84 percent.

The transition from a largely agrarian economy to an urban economy took only around 15 years. For the last three decades, anthropogenic impacts on the Central Arizona ecosystem primarily have been related to urbanization.

Current Economic Development

Though state and local governments in Arizona long have been focused on promoting economic development, a comprehensive economic development plan did not exist through four decades of rapid growth. Such a plan — Arizona Strategic Planning for Economic Development (ASPED) — was created at the beginning of the 1990s. However, only partial implementation of the plan has occurred.

ASPED stressed that the state should move from concentrating on growth of any kind to focusing on value-added activities in a limited number of economic clusters, particularly activities that pay moderate-to-high wages and produce relatively few deleterious effects on the environment. Eleven economic clusters currently are recognized. Six are "new economy" manufacturing activities: high technology (information and aerospace), the bioindustry, optics, software, environmental technology, and plastics and advanced composite materials. Two clusters aim to attract people: tourism and senior industries. Three are traditional activities: mining, transportation and distribution, and agriculture and food processing.

In addition, ASPED concentrated on improving the quality of six economic foundations: human resources (including education), financial capital, technology, tax and regulatory environment, physical infrastructure and quality of life. Such improvements would benefit all existing and potential companies and residents.

Regardless of the success of the plan, fast economic and population growth will continue in Central Arizona, with major disturbances to the natural systems continuing. The ASPED plan did not focus on sustainable development.

According to the President's Council on Sustainable Development, "a sustainable United States will have a growing economy that provides equitable opportunities for satisfying livelihoods and a safe, healthy, high quality of life for current and future generations. Our nation will protect the environment, its natural resource base, and the functions and viability of natural systems on which all life depends." Sustainable development presents a considerable challenge in Central

Arizona, with its large and growing human population dependent on water transported in from outside the area or on local sources that are not being fully renewed. Sustainable development will not be addressed in the balance of this paper.

Power Hierarchies

Public Sector

With the frontier spirit of the West and the associated desire for minimal government, the public sector in Central Arizona generally has not wielded much power. Historically, few restrictions were placed on the private sector and land use regulations were weak.

Through World War II, most residents of Maricopa County lived in unincorporated areas. With a weak county government, little power was exerted by local public-sector entities.

In 1948, a reformed city charter was adopted in the city of Phoenix. A charter government committee took control of city administration within a year. This committee was composed of conservative businessmen and the professional class. They set a strong agenda for growth, promoting spatial as well as industrial growth.

Nearly all of the urbanization in the 1950s was focused on the city of Phoenix or on lands annexed by the city during the 1950s. The proportion of the county's population living in the city of Phoenix jumped from 32 percent in 1950 to 66 percent in 1960.

For more than 50 years of statehood, the Arizona Senate consisted of two members per county, while the House of Representatives was apportioned by population. At statehood, Maricopa County was only slightly underrepresented in the Senate. However, the proportion of the state's population living in Maricopa County rose rapidly into the 1960s, reaching more than 50 percent, compared to its 7 percent share of Senate seats. Thus, power disproportionately remained in the hands of rural counties dominated by agricultural and mining interests. This changed in 1966 when the Senate was apportioned by population in response to a federal court order, giving more political power to the Phoenix area.

Private Sector

With the Central Arizona economy still largely agrarian until after World War II, a concentrated power base in the private sector also was missing. This changed radically after the war, with an active group of business leaders and the advent of charter government in Phoenix. With urbanization in the 1950s occurring almost entirely in the City of Phoenix, the power base of this select group developed further. Real power was wielded by a small number of private-sector leaders. Thus, public decisions were made in part by individuals who were motivated by profit maximization and who stood to benefit from growth.

In particular, these leaders largely came from business sectors, such as utilities, newspapers and banks, which were monopolistic or near monopolistic in nature. Only two utilities, which did not directly compete with each other, and one newspaper company controlled nearly 100 percent of their sectors. Banks were more numerous, but were protected against interstate competition, with a small number of large banks dominating the industry. Due to the protection against competition and the nature of their businesses — to serve the local population — each of these entities had a very strong vested interest in growth. They played a big role in producing the pro-growth attitudes and policies that persist today.

In addition, those who own fixed assets, such as land, receive a disproportionately large gain in value from the greater demand that accompanies urban growth. Large landowners, and those

who do business with these property owners, profit from growth and the associated increased intensification of land uses. Thus, this group also has a very strong vested interest in growth.

As urban growth continued in the 1960s and 1970s and spread from Phoenix into surrounding communities, the power base widened. Instead of a few private-sector leaders, there was the "Phoenix 40," a group of approximately 40 business leaders that included representatives from other industries, such as real estate and construction. The pro-growth bias broadened and became prevalent. In general, the perception of the bulk of the business community has been and continues to be that growth is good for business.

This concentration of power was enabled by so many residents of the Valley being relative newcomers. Most had no roots in the community and many were not sure that they would permanently reside in the Phoenix area. Further, most of the newcomers were young and preoccupied with personal issues such as careers and starting a family. Thus, the general public took little involvement in civic affairs such as policies regarding growth and land use. Moreover, many of the migrants, by moving west to a rapidly growing area, were predisposed to such concepts as laissez-faire economics and limited government involvement.

Since the 1970s, the strength of the exclusive private-sector group has waned, without being replaced by an identifiable entity. Charter government in the city of Phoenix was dissolved in 1975. Yet the same pro-growth private-sector interests continue to wield considerable power. County government remains weak and no real regional government exists. Though city governments have become more important, some are as pro-growth as their private-sector constituency.

These overarching pro-growth attitudes in the private sector and most of the public sector are not surprising given the lack of civic involvement and the generally conservative philosophy of the general public. While some urban residents express great concern over population growth, the majority of the population does not connect population growth to the issues about which they care, such as air quality and traffic congestion. According to David Berman in the Morrison Institute's *Arizona Policy Choices* report on growth, "Arizonans try to cope with growth while asking for more of it. There is considerable fear that increased controls will discourage further development."

Land Use and Management

Land Use and Change

Most of the land area in Maricopa County originally consisted of Lower Colorado River Sonoran Desert Scrub, a low elevation ecosystem featuring creosote and bursage. Most of the rest of the county was classified as Arizona Upland Sonoran Desert Scrub, a somewhat higher elevation life zone noted by an unusually large number of species due to biseasonal rainfall and varying terrain. Only in the far northeastern portion of the county is there much land at a higher elevation supporting other natural vegetative communities. Nearly all of the Phoenix urbanized area was built on Sonoran Desert Scrub, with the small amount of riparian lands along major watercourses also largely developed.

The aboriginal settlers transformed a small portion of the land, mostly to cropland along the Salt and Gila rivers. After they left around 1400, the land gradually reverted to a quasi-natural state, modified by a higher salt content and a higher water table.

Phoenix Area

With the arrival of Europeans in the mid-1800s, some of the natural vegetation in the Salt River Valley was cleared for farming. Much of the rest was employed for grazing. (Farming refers

to irrigated cropland or pastureland, while grazing occurs on the desert.)

In 1912, when Arizona became a state and just after Roosevelt Dam was completed, 9 percent of the land in the Phoenix area was used for farming, according to the Center for Environmental Studies' report on historical land use. Only 0.2 percent was urbanized. (About 4,422 square miles — a little less than one-half of Maricopa County's land area — is included in this definition of the Phoenix area.)

Over the next two decades, conversion of desert to farmland continued (see Table 4). Some of the expansion occurred on unused land in agricultural districts, while extensions of irrigated areas to the west and southeast opened additional land for farming. In 1934, 16 percent of the land in the Phoenix area was put to use for farming.

Dedicated land for recreation accounted for 0.5 percent of the total in 1934. Only 0.4 percent of the land was used for urban purposes. Nearly all of the modest expansion of the urbanized area between 1912 and 1934 took place on farmland, with Phoenix growing primarily to the north.

By 1955, the early expansion of the urban area was evident. Urban land use jumped to 2.7 percent of the total area, with expansion in all directions from central Phoenix. About five-sixths of the urban expansion between 1934 and 1955 occurred on farmland. A little more than 1 percent of the Phoenix area was dedicated to recreation.

Urban and recreational uses of the land steadily increased after 1955. By 1975, the urbanized area covered 6.6 percent of the land and the recreational share hit 3.3 percent. Urban expansion especially occurred in the southeast, northeast and northwest portions of the valley. Some of it was not adjacent to existing towns whereas urban growth before this had spread gradually from the core.

TABLE 4
LAND USE IN THE PHOENIX AREA

	Share of Total			
	Agriculture	Desert	Recreation	Urban
1912	9.0%	90.9%	0.0%	0.2%
1934	15.7	83.4	0.5	0.4
1955	13.8	82.3	1.2	2.7
1975	16.0	74.1	3.3	6.6
1995	11.3	66.4	4.4	18.0

	Source of New Urban Land	
	Agriculture	Desert
1912-34	98.2%	1.8%
1934-55	82.6	17.4
1955-75	39.9	60.1
1975-95	41.9	58.1

Source: Central Arizona-Phoenix Long-Term Ecological Research, “Phase I Report on Generalized Land Use.”

Unlike earlier periods, much of the urban development between 1955 and 1975 took place on unused or grazed desert land. About 40 percent of the urban development still occurred on farmland. However, farming also was expanding onto desert land. The share of the land area used for farming was marginally higher in 1975 than in 1934.

Recreational acreage continued to expand between 1975 and 1995, while urbanization accelerated considerably, going from less than 7 percent to 18 percent of the Phoenix area. Like the prior 20-year period, about 60 percent of the urbanization occurred on desert land and 40 percent on farmland. Most of the farmland conversion took place in the northwest and southeast portions of the Valley. Desert conversion happened throughout the Valley, but especially to the northeast.

Unlike the prior 20 years, farming did not expand onto desert land between 1975 and 1995. Thus farming's share was down to 11 percent of the land area in 1995.

Agriculture in Maricopa County

In the early 1950s, agricultural use peaked at close to 50 percent of Maricopa County's 5.9 million acres, according to the agricultural census conducted every five years by the U.S. Departments of Agriculture and Commerce. Most of these 2.7 million agricultural acres were used for grazing. Cropland was largely limited to the irrigated areas near the Salt and Gila rivers and accounted for not quite 10 percent of the county's total land area in the 1950s and early 1960s.

The decline in cropland has been largely continuous over time since the early 1960s, with especially large reductions in the 1980s (see Table 5). In contrast, rangeland decreased sharply from the mid-1960s to the mid-1970s and again in the late 1980s and early 1990s. Much of the decline in agricultural lands, particularly rangeland, occurred due to abandonment rather than to conversion to urban uses. By 1997, only 12 percent of the county's land was used for agriculture, with this equally split between rangeland and cropland.

Neighboring Pinal County, into which the Phoenix urbanized area now spills, has seen a similar decline in both rangeland and cropland. A higher proportion of Pinal County remains dedicated to agriculture than Maricopa County.

TABLE 5
AGRICULTURAL ACREAGE IN MARICOPA COUNTY

	Thousands Of Acres		Cropland	Percent Change	
	Total	Cropland	Share	Total	Cropland
1949	2,373	492	21%		
1954	2,711	581	21	14%	18%
1959	2,584	548	21	-5	-6
1964	2,518	584	23	-3	7
1969	1,899	542	29	-25	-7
1974	1,538	514	33	-19	-5
1978	1,413	509	36	-8	-1
1982	1,429	463	32	1	-9
1987	1,391	424	31	-3	-8
1992	730	376	52	-48	-11
1997	709	341	48	-3	-10

Source: Census of Agriculture, U.S. Department of Agriculture.

Urban Planning Area Projections

The Maricopa Association of Governments has defined an urban planning area in which development already has occurred or is expected within the next 20 years. Only 6 percent of the county's 1995 population did not live within this planning area, which consists of 1,768 square miles: 19 percent of Maricopa County's land area.

Even within this urban planning area, 53 percent of the land was vacant or used for agricultural purposes in 1995. By 2020, nearly all of these 936 square miles are expected to be developed.

Another 12 percent of the planning area (217 square miles) was dedicated to open space or consisted of water drainages and bodies of water. By 2020, this proportion is expected to double as more land is reserved as open space. However, the number of acres of dedicated open space hardly rose between 1990 and 1995, resulting in a 15 percent drop in per capita open space.

The rest of the planning area was used for urban purposes in 1995. Residential use accounted for 75 percent of these 597 square miles. The other 25 percent was split between public facilities, commercial, industrial and warehousing uses. By 2020, each urban use should account for a greater share than in 1995, with these urban functions using up three-fourths of the planning area, more than double the amount of land in 1995.

Land Ownership

Nearly two-thirds of the land in Maricopa County is publicly owned. The largest expanses of public land are the Tonto National Forest in the northeastern part of the county and various tracts, primarily in the western portion of the county, owned by the U.S. Bureau of Land Management (BLM). The BLM controls nearly four times as much land as the Forest Service.

As with Forest Service lands, BLM lands largely are used for cattle grazing leases, though they are managed under the doctrine of "multiple use." Some BLM land is administered as wilderness areas managed for wildlife habitat and limited recreation. While BLM lands are not sold outright, they can be traded and thereby come into private ownership.

The Arizona State Trust also controls a considerable amount of land in the county, especially north and northwest of the urbanized area (see the *Urban Atlas* produced by the Maricopa Association of Governments). Like the BLM lands, state trust lands primarily are used for grazing. Statewide, grazing leases are held on 93 percent of the state trust lands.

Unlike the BLM lands, state trust lands can be sold, as well as leased and exchanged. With proceeds from the disposal of trust lands benefiting public uses, especially the education system, state trust lands historically have been developed under the concept of "highest and best use," with sales for less than the appraised fair market value prohibited. Some of the developed land in the urbanized area once was state trust lands.

About 5 percent of Maricopa County is controlled by five Indian communities. Three border the urbanized area, including the Gila River Reservation to the south and the Salt River Pima-Maricopa and Fort McDowell Mohave-Apache communities in the northeast. Other public lands include federal, state, county and city parks, preserves and open spaces.

Privately owned land largely is confined to the urbanized area, the farmlands southeast of the urbanized area, and lands west of the urbanized area, extending for some distance near the major transportation routes of I-10 and State Route 85/I-8.

In neighboring Pinal County, a much lower proportion of the land is federally owned than in Maricopa County. Indian tribes and the Arizona State Trust control much higher proportions.

Land Management

The bulk of the public lands in Maricopa County are managed under the multiple-use doctrine. Other than use by off-road vehicle riders, hikers and other recreationists, the public lands primarily are used for grazing. Exceptions include federal wilderness areas, regional parks and mountain preserves where grazing is not allowed. Some of the land in the Indian communities bordering the urbanized area is used as cropland.

Even lands in protected status may have been changed by human activities. Some still are affected by mismanagement in the past, such as overgrazing. In some cases, the natural vegetative community has been altered by the large number of exotic plant species introduced into Central Arizona, mostly by choice by urban residents, farmers and ranchers. Overexploitation of natural resources, such as excessive hunting and gathering, and especially the pumping of groundwater that continues today, can affect extensive areas.

In the urbanized area, cities have the primary land-management jurisdiction. Thus, land-use policies vary from place to place.

The issue of land-use policy currently is being analyzed in the Growing Smarter process, created by the Governor and the Legislature. An alternative proposition, the Citizens' Growth Management Initiative, may be on the ballot in November 2000.

Planning

Inadequate planning ranks sixth on the Nabhan and Holdsworth list of threats to the Sonoran bioregion. According to David Berman in *Arizona Policy Choices,* growth management in Arizona has had to struggle with the values of individualism, economic development and localism. Arizona has looked at land use control as a local issue, not a regional or state activity. However, ineffective planning results in part from a weak public sector with no regional government. The Maricopa Association of Governments is trying to fill some of the void, but lacks the authority that a true regional government would have.

People's attitudes and perceptions underlie the weak regional government and inadequate planning. Berman states that as one of the last frontiers in the movement west, Arizona long has been a place associated with frontier freedoms. Individualism is one of the frontier values, encompassing the freedom to think and act as one pleases, as well as valuing self-reliance.

Another frontier value is an emphasis on material accumulation. This includes "entrepreneurial freedom, a willingness to undertake risks, an optimistic view of one's chances of getting ahead in life, and an exploitative attitude toward natural resources" (Berman). Mark Pastin (quoted by Berman) linked the popular adherence to frontier themes regarding the unfettered development of natural resources to the difficulty the state has had in putting together a consistent policy on environmental quality.

Despite the substantial population growth and heavy urbanization of recent decades, Arizona still is perceived by many citizens locally and around the country as a place to get away from government and to be able to do as one pleases. Thus, a disproportionate share of migrants continue to be of like mind. This portion of the population has fought comprehensive planning and other government actions, especially those affecting property rights.

Fast growth complicates any planning done in Central Arizona. The public sector has difficulty keeping up with the need for infrastructure, such as roads and schools. The expense of building this infrastructure adds to the tax burden or shifts spending away from services provided directly to residents.

Public Opinion

Considerable criticism has been levied from many quarters regarding inadequate planning for growth in Central Arizona. In the 1995 survey by Tribune Newspapers, 46 percent of the respondents thought that local governments and policymakers were doing a fair or poor job "in developing effective policies regarding growth and quality of life in the Valley;" 48 percent thought they were doing a good or better job.

The job done "in developing effective policies regarding desert and mountain preservation in the Valley" was rated by 50 percent as fair or poor, compared to 43 percent responding good or excellent. The responses to the same question were less favorable in the 1998 Morrison Institute survey, with 61 percent answering fair or poor and only 36 percent good or excellent.

Seventy-seven percent thought "local governments should take a role in trying to preserve the undeveloped desert and mountain lands." One-third of those surveyed thought that local government underregulated residential developers and homebuilders compared to 17 percent who answered that government overregulated them. Thirty-nine percent responded "about right." In the Morrison Institute survey, 64 percent thought that local government should manage growth, compared to 28 percent who answered state government.

Designed Environment

An urbanized area generally consists of contiguous land of moderate or higher population density, as defined by the U.S. Bureau of the Census. In 1990, 95 percent of Maricopa County's population lived in the Phoenix urbanized area. Yet the urbanized area (741 square miles) encompassed just 8 percent of the county's area. When urbanized areas first were defined in 1950, only 65 percent of the county's residents lived in the Phoenix urbanized area.

The population density of the urbanized area was 2,700 persons per square mile in 1990, up from 2,200 in 1980. Even with the increase in density in the urbanized area from 1980 to 1990, the Phoenix area's population density remained low relative to other urbanized areas.

Urban Form

Sprawl

Many critics contend that the Phoenix urbanized area sprawls across the desert. However, the term "sprawl" is overused and given a variety of meanings, to the extreme of encompassing any urban growth in land area size. According to Larry Landry in *Arizona Policy Choices*, "Many participants in today's debate misunderstand, or misuse, the term ‘urban sprawl.’"

Landry goes on to define sprawl as development of significantly lower density than typical metropolitan urban development, scattered over the countryside in a manner that increases dependence on auto travel, that cannot be efficiently served by public utilities and other infrastructure systems, and that may threaten environmental resources. At its core, sprawl involves losing density from an existing portion of a city or urbanized area to another, newer area further from the urban center (Grady Gammage in *Arizona Policy Choices*).

Sprawl results from some combination of leapfrog, scattered and very low-density residential development. At its worst, sprawl is long lasting (infill does not occur and densities do not rise) and covers extensive areas. Moreover, few jobs and services are available nearby.

"Sprawling, low-density residential development cannot generate sufficient tax revenues to pay for the infrastructure, public facilities and services such as schools and law enforcement. The result is a drain on the financial resources of cities, counties and school districts and even more

taxes on businesses and residents in urban development areas." (Landry).

Philip Langdon in *Arizona Policy Choices* summarizes by stating that "When looked at as a package, sprawl, with its combination of environmental costs, economic costs, traffic, tax burdens, and urban deterioration, looks more and more like a bad deal."

While western urbanized areas are frequently cited as examples of sprawl, classic undesirable sprawl really is a feature of older urban areas in the eastern two-thirds of the nation that are experiencing little or no overall population growth while still expanding in geographic size. Low overall densities with substantial areas of scattered low-density development especially occurs in the Midwest and South, where land prices are low.

Population densities and the change in densities are highly correlated to land prices. Where prices are high — the West and Northeast — densities are relatively high and rising or declining only slightly. For example, the Los Angeles urbanized area in 1990 had the highest population density of any urbanized area in the country, with an increase in density between 1980 and 1990.

"Compact development" is at the other extreme from sprawl. In areas with high land prices, some degree of compact development occurs naturally. Growth management and planning contribute to compact development.

The Phoenix Area

The Phoenix area is neither an example of compact development nor sprawl. Its somewhat low population density places it toward sprawl on the compact development-sprawl continuum. The low density results from moderate land prices and limited growth management and planning.

Much of the development at the edge of the Phoenix area has nearly the same density as the inner rings. Thus, variations in density are not as wide as in older, eastern urbanized areas. With substantial vacant land, even the downtown-midtown corridor has a relatively low density. Similarly, while the Valley has inferior, low-cost housing, it largely exists in a low-density setting.

Rapid population and business growth erases most examples of sprawl relatively quickly by filling areas that were initially passed over for development. The Phoenix area's density continues to rise as infill and the building of urban cores continues at the same time as growth on the edge of the area. Thus, the Phoenix area is not following the eastern pattern of sprawl.

For the most part, the Phoenix urbanized area has been designed much like any other U.S. urbanized area, despite its location in the hottest, sunniest, driest region of the country. Frequently, buildings have not been designed specially to block out the summer sun or insulate against the summer heat. Thus, power use is very high in the summer.

Similarly, the outdoors portion of the built environment has more resembled a midwestern city than the desert. The result is one of the highest consumption of water in the country on a per capita basis, some 50 percent greater than in Tucson.

As in most urbanized areas, the quality of housing varies widely across the Phoenix area, matching the wide range in household incomes. For example, housing values reported in the 1990 census averaged less than $40,000 in South Phoenix and in much of the outskirts of the urbanized area, but more than $150,000 in other neighborhoods.

In other respects, the Phoenix area is unusual. A high percentage of the land area is covered by concrete and asphalt, a result of being built during the automobile era, with little public transit. In particular, the Phoenix area has wide roads and numerous parking lots.

The housing stock is dominated by single-family detached houses, most of these with three bedrooms. This concentration in one housing type is far different than in San Diego, for example, which has a greater assortment of apartments, townhouses and single-family houses, of varying

sizes. Similarly, most of the housing (and non-residential development) in the Phoenix area was built relatively recently with designs that at any time did not vary much from builder to builder. This has resulted in a perception that much of the Phoenix urbanized area consists of suburban housing tracts that look much the same.

The Phoenix area also is unusual in its substantial amount of open space within the urbanized area boundaries is found. In addition to large mountain preserves, numerous golf courses and some farming, planned communities are common in the area, many of which have reserved open space in the form of greenbelts and lakes.

HUMAN-INDUCED PROCESSES INFLUENCING LONG-TERM ECOSYSTEM DYNAMICS

From the first settlement of Central Arizona by Europeans in the 19th century through the first half of the 20th century, agriculture — both farming and ranching — was the human activity that had the most effect on the natural ecosystem. Clearing land for farms substantially transforms the physical and biological ecosystems. The lack of adequate rainfall to grow crops results in substantial use of irrigation. Rather than affecting only the cultivated areas, farming in the desert has much more widespread effects from activities such as groundwater pumping, dam building and construction of canals. The aquatic ecosystem is further affected by the use of pesticides and fertilizers.

The physical and biological ecosystems also are transformed by the introduction of grazing livestock and exotic plants to feed these animals. The effects of the severe overgrazing that occurred in the past can still be observed.

Over the last 50 years, urbanization has been the human process most affecting the natural ecosystem. Urbanization almost completely transforms the physical and biological ecosystems. The hydrologic effects of urbanization in Central Arizona are not as severe as from farming. However, physical alterations to the ecosystems, air pollution, climate change, and soil contamination are among the disturbances primarily related to urbanization.

Physical And Biological Alterations Of Terrestrial Ecosystems

In Central Arizona, terrestrial alterations are the most important of human disturbances to the environment. Such impacts currently are tied primarily to population growth and urbanization, the top two threats to the bioregion according to Nabhan and Holdsworth. They state that urbanization has numerous and mutually reinforcing effects on biodiversity. The University of Arizona in Arizona Town Hall Report 59 stated that loss and degradation of habitat is the greatest threat to wildlife and that entire biotic communities have been lost to urbanization.

In the 1997 special report on human-dominated ecosystems in *Science* magazine, land transformation was cited as the primary force in the loss of biodiversity, with the effects extending beyond the boundaries of the transformed lands. More generally, the use of land to yield goods and services was noted as the most substantial human alteration on the earth system. This use modifies the structure and functioning of ecosystems and alters how ecosystems interact with the atmosphere, aquatic systems and surrounding land.

Under the federal Endangered Species Act, 87 Arizona species are listed as threatened or endangered and another 129 are candidates for listing. Nine species have disappeared from Arizona but are found elsewhere, and nine species are extinct.

Most of Central Arizona consists of the ecosystem ACERP designated as hot scrublands. Main stressors to this terrestrial ecosystem are grazing, species introduction, illegal collecting, recreation, urbanization and mining (see Table 6). In Central Arizona, mining is a minor factor but urbanization is a much greater stressor than in other hot scrublands, such as those in the western part of the state.

Physical Alterations - Agriculture

Until the last 50 years, the greatest factor affecting terrestrial ecosystems in Central Arizona was agriculture. Farming involves the complete removal of vegetation, leveling, serious soil disturbance, major changes to hydrology, and erosion. The natural system has no resistance to such

major changes and limited resilience due to increased salinity and groundwater drawdown. Riparian systems especially are affected. Thus, even when abandoned, agricultural lands take decades or centuries to recover. Farming causes habitat fragmentation as well, resulting not only from the clearing of natural habitat to grow crops, but from such factors as irrigation canals crossing otherwise undisturbed areas.

Ranching can lead to the degradation of wide expanses of the natural ecosystem. Some areas still suffer from extreme overgrazing which occurred in the late 1800s. According to Nabhan and Holdsworth, overstocking still continues on public and private lands in Arizona. Grazing causes trampling of vegetation, compaction of soil, disturbance of the soil surface, and increased erosion. It also leads to species competition. The natural system largely lacks resistance to these effects. In addition, ranchers have introduced exotic grasses and forbs. Even if grazing is discontinued and some recovery to the natural ecosystem occurs, the exotic plants remain.

Physical Alterations - Urbanization

In recent decades, urbanization has been the key human activity affecting the Central Arizona ecosystem. While some urbanization has transformed lands already substantially modified by farming, in other cases it has proceeded on relatively undisturbed lands or on lands modified only by grazing.

TABLE 6
STRESSORS TO HOT SCRUBLANDS ECOSYSTEM

High
Grazing
Species Introduction and Control

Medium
Urbanization
Recreation
Illegal Collecting
Extractive Mining

Low
Accidental Releases
Air Pollution
Agriculture
Highways/Roads
Energy Production
Interbasin Water Transfers
Channelization
Water Diversion
Hunting
Fire
Timber Management

Source: Arizona Comparative Environmental Risk Project, Ecosystems Committee.

Urbanization usually involves a very high degree of habitat conversion: the nearly complete destruction of the natural ecosystem, replaced by a human-built environment. Where the effect is not as great, human population growth still results in fragmentation of the natural ecosystem into small pieces that often are unable to support viable populations of native plants or animals.

The effects of urbanization derive both from the sheer number of people living in the Phoenix area and their activities. For example, limited mass transit and a dependence on personal vehicles results in a greater proportion of the developed area being dedicated to roads and parking lots than would otherwise be necessary. The distribution of economic activities also affects the natural ecosystem. The Phoenix area has relatively less manufacturing than most urban areas and therefore less land allocated to industrial purposes.

Urbanization's impacts extend beyond the boundaries of the urbanized area. For example, the need for energy production to serve the urban area results in disturbances to otherwise largely unaffected areas, such as at the Palo Verde Generating Station west of the urbanized area. Similarly, landfills usually are sited well away from developed areas.

Off-road recreational vehicle use compacts soil, damages vegetation, and leads to greater erosion. Highways are built or widened through otherwise relatively undisturbed natural areas. Not only does this destroy habitat, but it leads to road kills and isolation of animal populations. The ecosystem lacks resistance to these effects.

Thus, at one extreme is the transformation of land for row-crop agriculture, pastureland, and urban-industrial areas, which almost fully transform the natural systems. At the other extreme is land barely transformed by man. However, most ecosystems have been utilized in the past for hunting and low-intensity resource extraction, and all are affected by the worldwide increase in carbon dioxide. Grazing falls in between the two extremes. Since agriculture and urbanization occur primarily in areas with groundwater and surface water — which support the most diverse natural ecosystems — the effects of the land transformation are all the more significant.

Biological Alterations

Beyond the physical alterations from agriculture and urbanization, other human activities have had a direct effect on the biology of the ecosystem: hunting (especially predator control), overintensive plant collecting of selected species, killing of wildlife by automobiles, toxics and pets, and disturbances to mating and nesting.

Three items on Nabhan and Holdsworth's list of threats are related to biological invasions and the introduction of exotic grasses. The special report in *Science* identified human-introduced biological invasions as the second most important cause of extinctions worldwide, after land transformation. Species introduction has affected nearly the entire Sonoran Desert region.

In Central Arizona, farming and ranching deliberately have introduced exotic species, in particular non-native grasses for revegetation, erosion control and provision of feed for livestock. In addition, cattle have had major detrimental effects on riparian areas.

Exotic species introduced by urban dwellers may colonize undisturbed areas away from the developed area. For example, fountain grass grows on the north side of Camelback Mountain. Some exotic species, such as olives and mulberries, are major sources of pollen.

Accidental introductions of insects, pests and diseases also occur. In the Phoenix area, fire ants, killer bees and a variety of grasses and weeds are not natural components of the ecosystem.

Other

Human activity and management practices can increase the incidence and severity of natural hazards. Since the Sonoran Desert is not adapted to fire, human-caused fires can have a significant and long-term effect. Other human activities, such as mining, can have substantial effects on the natural ecosystem, but these are not significant issues in Central Arizona.

Land and Soil Contamination

Land and soil contamination can occur near farms, landfills, illegal dumping sites and urban areas. Land and soil contamination was considered a medium-level threat by ACERP. The public survey conducted by ACERP revealed that considerable concern exists regarding the disposal of hazardous waste, and that overall waste disposal also is a concern. Discussions of waste disposal distinguish between hazardous waste and municipal solid waste (MSW).

Hazardous Waste

Hazardous waste consists of material that may pose a threat to human health or the environment. Disposal and handling of hazardous waste materials are regulated by federal law. Industrial operations may use chemicals such as polychlorinated biphenyls (PCBs), acids, ammonia, solvents, and petroleum products. Most of the hazardous waste generated by industrial or other large sources are disposed of properly, but accidental spills can occur, coming during the transportation, production, storage and use of hazardous products. Improper disposal in the past still plagues some areas with land and groundwater contamination.

Most household hazardous waste goes into local landfills or into the sewer system. However, more disposal programs are being developed by Valley cities to accept hazardous waste from households.

Municipal Solid Waste

MSW includes durable and non-durable goods, containers and packaging, food and yard wastes, and miscellaneous organic wastes from commercial, industrial and residential sources. In addition, municipal sludges, combustion ash and industrial non-hazardous waste may be disposed of in landfills.

Seven landfills are located at the fringe of the Phoenix developed area, mostly older municipally or privately run sites. Illegal dumping sites continue to be discovered. In 1999, a medical waste site was found near the old Williams Air Force Base. Other contaminating substances that may be found in landfills and illegal dumpsites include lead, heavy metals, cleansers, paint thinner, lead paint and asbestos.

Contaminations

Sources of land, soil and groundwater contamination include seepage from landfills, improper disposal of hazardous materials in landfills, and spills, such as accidental releases. Leaking storage tanks, especially below ground, also are a common source. Most of the leakage is of petroleum products, with a small portion also contaminating the groundwater. Other pollutants posing significant hazards are benzene, trichloroetheylene (TCE), chromium and mercury.

Farms use a substantial quantity of fertilizers, especially nitrogen and phosphorus. Monocultures lead to pest problems, thus pesticide use is high, especially in the category of insecticides and herbicides. As agricultural lands are converted to urban land uses, potential exists for pesticide contamination in areas heavily used by humans.

The majority of the agricultural chemicals are assimilated by the plants, degrade, leach below the root zone, volatize or are transported by sediments and run off into surrounding environments. Some accumulate in the soil, such as arsenic-based defoliants, stable organic herbicides and insecticides, metals and salts. Currently used pesticides have short half-lives, degrade quickly and have moderate-to-low toxicities in humans and animals. However, residual levels of DDT and similar chemicals remain from 30 years ago, including along the Gila River and in west-central Phoenix.

Physical and Biological Alterations of Aquatic Ecosystems

Surface water impoundment and diversion ranks third on Nabhan and Holdsworth's list of threats while aquifer mining and its effects rank fifth. Among U.S. Federal Register notices listing plants and animals as endangered species, water diversion and impoundment are among the most frequently cited threats.

High stressors to aquatic ecosystems according to ACERP include grazing, agriculture, water diversion, pumping, impoundment and dams. A full list, by type of aquatic ecosystem, is shown in Table 7. In Central Arizona, mining and timber management are less important, while urbanization is a greater stressor, than indicated in the table.

TABLE 7
STRESSORS TO AQUATIC ECOSYSTEMS

Stressors	Overall	Riparian	Lake and Reservoir	Streams, Rivers
Agriculture	HIGH	MEDIUM	HIGH	HIGH
Grazing	HIGH	HIGH	HIGH	MEDIUM
Water Diversion	HIGH	HIGH	LOW	HIGH
Impoundments & Dams	HIGH	MEDIUM	—	HIGH
Pumping	HIGH	HIGH	LOW	HIGH
Species Introduction	HIGH	HIGH	HIGH	HIGH
Energy Production	MEDIUM	HIGH	MEDIUM	MEDIUM
Channelization	MEDIUM	HIGH	LOW	MEDIUM
H20 Contam Non-Point	MEDIUM	MEDIUM	HIGH	MEDIUM
Groundwater Contam	MEDIUM	—	LOW	MEDIUM
Mining	MEDIUM	MEDIUM	LOW	HIGH
Timber Management	MEDIUM	MEDIUM	MEDIUM	MEDIUM
Urbanization	MEDIUM	MEDIUM	LOW	MEDIUM
Accidental Releases	LOW	LOW	LOW	MEDIUM
Highways	LOW	LOW	LOW	MEDIUM
Water Transfers	LOW	LOW	LOW	MEDIUM
Point Source Contam	LOW	LOW	LOW	MEDIUM

Source: Arizona Comparative Environmental Risk Project, Ecosystems Committee.

Riparian Ecosystem

The riparian ecosystem consists of lands dependent on water sources and makes up only a small portion of the Central Arizona landscape. However, this is a biologically rich ecosystem on which many animals depend.

Most riparian areas in Central Arizona have been substantially altered by humans. Alterations related to agriculture and urbanization are numerous.

Farming

The need to irrigate crops in Central Arizona has led to a wide network of dams and canals. The majority of riparian areas are downstream from dams, with many systems totally degraded from lack of water flow. Water diversions affect the majority of riparian areas and have a long-term impact.

Farming also has pumped considerable groundwater for irrigation purposes. Groundwater withdrawal in the Salt River Valley increased from 4.5 million acre-feet in the 1920s to 21.9 million in the 1950s. The figure was down to 10.2 million in the 1980s. The declines in groundwater use in recent decades have been due to farms being replaced by urban areas and increased pumping costs, which result from a lowered water table.

Pumping has exceeded natural recharge since the early 1900s. It lowered the water table in the Salt River Valley from 181 feet below the surface in 1945 to 378 feet in 1985. A modest rebound to 365 feet was measured in 1990. This lowered water table caused the surface water in some riparian areas to be reduced or eliminated, resulting in ground subsidence, an increase in salinization, and the demise of riparian forests. Riparian systems have little resilience to groundwater withdrawal.

Farming has had other significant effects on aquatic ecosystems, with riparian systems particularly impacted. Soil disturbance, the removal of riparian vegetation and the introduction of exotic species have greatly weakened the resistance of the natural system. When combined with little natural flow, increased soil salinity and groundwater drawdown, the ecosystem's recovery after agriculture is abandoned is limited, and takes decades to achieve.

Other Alterations

Grazing has a high impact on riparian areas through vegetation degradation, species loss, soil compaction and streambank disturbances.

Urbanization has caused many of the same disturbances to the aquatic ecosystems as farming. Dams and other modifications to natural watercourses have been built for urban purposes, such as for flood control, recreation and hydroelectric power. In riparian areas, the disturbance from highways and bridges is long term and nearly complete. Crossings affect stream dynamics due to the use of sand and gravel.

Streams and Rivers

All of Central Arizona is within the Salt-Gila river system. The largest tributaries are the Agua Fria, Hassayampa and Verde rivers. The latter carries the region's only major perennial flow. The stressors affecting the region's streams and rivers are similar to those of riparian areas (see Table 7).

Channelization — restricting the breadth of a watercourse, frequently aligning it into artificial configurations — affects the majority of streams and rivers, including the Salt River. It is done to enhance development along the watercourses and to expedite water movement, reducing

the duration of flooding. Channelization often is accompanied by bank hardening to force the stream to stay within the channel.

Effects of channelization include removal or subsequent loss of riparian vegetation, increased sediment loads downstream and various effects on stream characteristics. The problems are more extreme if the channels are lined with concrete or if urbanization goes to the edge of the channel. Disturbances extend upstream and downstream from the channelized portion. If channelization is abandoned, recovery is slow and incomplete.

Water diversions reduce the overall input into the stream and river system, trapping nutrients and sediments and reducing infiltration into groundwater. Increased runoff from urban areas during storms increases erosion in streams and can cause toxic depositions and sedimentation.

Lakes and Reservoirs

Seven major reservoirs are found outside the Phoenix area: two in the Verde River drainage, four along the Salt River, and one on the Agua Fria. Reservoir levels vary widely by season and year due to fluctuations in urban and agricultural uses and variations in precipitation.

Natural lakes are absent in Central Arizona. However, many small artificial lakes have been created over the last 25 years in the urban area.

Interbasin water transfers, such as Colorado River water entering the Salt River Valley via the Central Arizona Project canal, allow biological movement of organisms across basins. Physical and chemical changes to reservoir water can result if the transferred water is of a different quality.

Many of the problems discussed in the prior sections on riparian areas and streams and rivers affect the reservoirs in that the reservoirs receive the waters carried by streams. Reservoir impairment is high in the middle of the Salt and Gila basins.

A primary problem is low levels of dissolved oxygen resulting from the increased nutrients produced by agriculture. While in part naturally occurring, high levels of dissolved solids and salinity are deposited from return flows from irrigation canals. Hydromodifications cause inundation of soils high in toxic compounds. Arsenic is a particular problem in the Salt and Verde drainages.

Reservoirs are subject to eutrophication: enrichment by inorganic nutrients, especially nitrogen and phosphorous. The process is enhanced by land use activities and wastewater discharges, resulting in increased aquatic plant growth and reduced fish populations. Sedimentation — filling of basins by fine sediments transported in — also can occur.

The deposition of toxic compounds can come both from direct discharges and indirect sources. While some bind to substrate and may be buried, others may stay in the water. Reservoirs also are subject to temperature variations, which can interact with eutrophication and toxicity.

Biological Alterations

In addition to overfishing of native species, sport fishing has introduced exotic species that often have outcompeted native species. ACERP listed species introduction as a high stressor to aquatic ecosystems. The stocking of exotic fish, accidental species introduction and development along reservoirs and watercourses all affect the natural balance of the ecosystem.

Water Quality – Groundwater and Surface Water

Central Arizona's water supply derives from four sources: surface water from the Salt River and other local streams, surface water from the Colorado River delivered through the Central Arizona Project (CAP), groundwater, and effluent (reclaimed water). Historically, local surface

water and groundwater provided nearly all of the region's supply, in roughly equal shares. In the last 15 years, CAP water has substituted for both local surface water and groundwater, and effluent use has increased a little. Still, groundwater and local surface water provide some 80 percent of the water used, in roughly equal shares.

ACERP rated groundwater contamination as an issue of high importance. Surface water contamination and drinking water contamination were assessed to be medium risks. However, in the public survey conducted by ACERP, safe drinking water in the future was the issue of most concern, with the current quality of drinking water ranking second. In addition, the quality of surface water was an above average concern.

In the 1998 Morrison Institute survey, only one-fourth of the respondents said they drank tap water. That so many drink filtered or bottled water provides strong evidence of negative perceptions of water quality.

Groundwater

Groundwater pollutants may come from a variety of sources, including sewage treatment plants, landfills, agricultural operations, hazardous waste sites, septic tanks, leaking storage tanks and improper disposal of waste from industrial sites.

Thirty-one superfund sites have been identified in the Phoenix area. They mostly involve groundwater contamination, though some have soil and surface water contamination.

Many wastewater treatment facilities are located throughout and just outside the developed area. They typically are managed by municipalities or master-planned communities.

Many aquifers show the impact of agriculture, including those in the east and west Salt River Valley. Of greatest concern are nitrates and total dissolved solids (TDS), a gross measure of salts concentrated in water. Concentrations typically are higher in shallow groundwater than at deeper levels of the aquifer.

Surface Water

Surface water contamination comes from point discharges and non-point (indirect) sources. Contaminants include ammonia, chlorine, metals, nutrients and sewage.

Point discharges include by-products of mining, energy production and industrial activities, as well as discharges from sewage treatment plants. Boats leave oil, grease and wastes that are thrown overboard. In addition, the water treatment process introduces aluminum from the handling of municipal sludge, and chloroform and other trihalomethane compounds from disinfecting drinking water.

Non-point pollutants include pesticides, petroleum chemicals, nutrients, sediments and fecal matter. They come from varied sources such as urban storm runoff; leaching from septic systems; runoff from hazardous waste sites, farming, livestock grazing and construction; and damage to shorelines from off-road vehicles. Nearly all riparian areas are affected by non-point sources.

Agriculture

According to the Arizona Department of Environmental Quality, agriculture is the predominant source of contamination in the rivers and streams ecosystem, through range management, crop production and concentrated livestock feeding. Combined with flow depletion, agriculture is responsible for significant water quality degradation. Agriculture can lead to drinking water contamination from substances such as nitrates, pesticides, petroleum hydrocarbons, volatile organics, chlorinated solvents, bacteria and salts.

Farming contributes to contamination of reservoirs as its by-products from throughout the watershed are transported to the reservoirs. Fertilizers and pesticides add nutrients and toxics. Soil preparation may lead to erosion and sedimentation. Irrigation discharges have been linked to turbidity and contaminations of surface water by pesticides, ammonia, nutrients and salts. All have significant long-term effects, as natural resistance, resilience and restoration of aquatic ecosystems all are compromised by eutrophication.

Grazing also has a strong negative effect on reservoirs. Animal wastes increase nutrients and bacteria, while sedimentation rises from the loss of vegetative cover and streambank trampling. These disturbances produce long-term effects, with low resilience and restoration.

Air Quality

Most airborne pollutants in Central Arizona result from the combustion and leakage of "fossil fuels." The primary source of air pollution in Central Arizona is gasoline- and diesel-fueled internal combustion engines in trucks and automobiles. Other sources include gas stations, aircraft, lawn mowers and other gasoline-powered tools. Industrial operations, agriculture, dry cleaners and fireplaces affect air quality from agents other than petroleum products.

In general, air pollution in Central Arizona does not persist at high levels over a long enough time to cause significant effects on local ecosystems. In localized areas near major pollution sources, effects may be greater. However, because of health risks to humans, ACERP rated air quality as the only environmental issue of very high concern.

Major Pollutants

Criteria for maximum allowable concentrations in the air have been established for six pollutants: particulates, carbon monoxide, ozone, nitrogen oxide, lead and sulfur dioxide. The first three are of particular concern in Central Arizona and are regularly monitored in the Phoenix area.

Particulates are solid particles or liquid droplets small enough to remain suspended in air. They include smoke, dust, soot and toxic particles. They result from incomplete combustion of fuels, especially diesel, and wind-blown dust from paved and unpaved roads, construction sites, plowed fields and mine tailings. The EPA has set a standard for particulates less than 10 microns in diameter, which was exceeded four times in the Phoenix area during the 1990s. Only these fine particles can be inhaled into the respiratory tract.

Carbon monoxide is a poisonous gas resulting from incomplete fuel combustion; 70 percent comes from motor vehicle exhaust. It is primarily a winter pollutant because early sunsets lead to temperature inversions during the evening rush hour, trapping exhausts. The stagnant, polluted air is still present during the morning rush hour, before dispersing during the middle of the day. Carbon monoxide standards were violated 18 times during the 1990s in the Phoenix area. Violations occurred on at least 19 days in every year of the 1980s.

Ozone also is a poisonous gas, formed in the atmosphere by chemical reactions between volatile organic compounds and oxides of nitrogen. It is a problem during summer days, since sunlight and heat are required for its formation. Ozone exceeded federal air quality standards on 34 days in the 1990s, about the same number as in the 1980s. Principal sources are motor vehicles, lawn and garden equipment, construction equipment and dry cleaners. Ground level ozone also harms vegetation, both agricultural and native.

Among the nitrous oxides is nitrogen dioxide produced by internal combustion engines, especially those using diesel fuel. Nitrogen dioxide is brown, the most visible part of smog. Photochemical smog is a secondary pollutant formed from atmospheric chemical reactions between

hydrocarbons and nitrous oxides in the presence of sunlight. Smog mostly results from vehicle emissions, especially from diesel fuels. It is a brown haze reducing the amount of sunlight that reaches the ground.

Hydrocarbons come from leaks and evaporation from fuel systems, gas pumps and carburetors. Other sources include the petrochemical solvents used by dry cleaners and paint factories. Hydrocarbons are precursors of smog, reacting with chemicals in the air.

Hazardous air pollutants (air toxins) are chemical compounds such as lead resulting from industrial activities, vehicle emissions, agricultural activities and home heating. Other air pollutants are not common in Central Arizona. These include sulfur dioxide, which is caused by smelting operations and high-sulfur coal combustion and leads to acid rain falling some distance from the pollution source.

Public Perceptions

In the 1998 Morrison Institute survey, 88 percent of the respondents rated the Phoenix area's air quality to be fair or poor. They perceived that the regional air quality posed a health hazard: 29 percent thought it to be very dangerous and an additional 54 percent answered "somewhat dangerous."

The general public does not seem to connect vehicle miles traveled to air quality problems about which they express considerable concern. This is similar to the lack of concern about population growth, which exacerbates nearly all perceived quality-of-life problems. The 1995 survey by Tribune Newspapers asked "when you buy a home, do you consider the following factors very important?" More than 70 percent answered yes to "price," "privacy," and "sense of neighborhood," while only 44 percent answered affirmatively to "distance from work."

Other

Other human impacts on the environment of Central Arizona include climatic effects. When the desert was converted to farmland, more moisture was put into the air. This has been reversed as urbanization has replaced farmland. Effects on rainfall have been insignificant.

The expanse of concrete and buildings, as well as exhausts from human activities, has created an urban heat island. The effect is greatest at the urban core. While daytime temperatures have hardly been affected, nighttime temperatures are warmer than in the past, with the temperature difference between the urban core and the outlying farmland or desert greater than in the past.

More broadly, Central Arizona may be affected by global climate change and atmospheric ozone depletion resulting from human activities. The degree of effect on the local area is uncertain.

Other impacts from the human presence in Central Arizona include an increase in airborne allergens and infectious agents such as pollens, molds, bacterias and viruses. Pollens and molds in Central Arizona mostly come from non-native species.

Exposure to man-made ionizing radiation is limited in the urbanized area since it results from nuclear power plants and activities concerning uranium fuels. Non-ionizing radiation is more common, coming from microwave and radio frequencies and electromagnetic fields (such as overhead lines used for energy transmission).

In addition to effects on natural ecosystems, increased human activity can lead to a degraded built/cultural environment. Noise pollution, loss of visibility (from air pollution, buildings, signs and utility lines), light pollution, litter, odors, and the loss of open space are examples. Noise pollution is especially severe near Luke Air Force Base and Sky Harbor International Airport, with a lower level of noise at other airports such as Williams Gateway and Scottsdale.

EFFECTS ON HUMANS FROM ECOSYSTEM MODIFICATIONS

As humans alter the natural ecosystem, these changes in turn affect humans. Most impacted are public health, health care costs, quality of life, and spending patterns by individuals, governments and companies.

Alterations to the natural ecosystem can have ecological, psychological, sociologic and economic effects on residents of Central Arizona. Hydrologic changes have affected both the quantity and quality of water. Poor air quality has had numerous effects on humans.

Overview

Human activities have ecological consequences that in turn affect human conduct. These effects particularly are seen in human health and health care costs, other quality-of-life concerns and other economic considerations. All of these issues are interrelated.

The quality-of-life committee of ACERP looked at seven criteria in assessing environmental impacts on the quality of life (see Table 8). Air pollution and the physical/biological alteration of ecosystems each were assessed as having high economic and overall impacts.

Economic Costs

Pollution of land, water and air as well as alteration of the natural ecosystem all create human health risks and associated increases in health care costs. Due to the use of sick leave and reduced efficiency while working, a less healthy population is an economically less productive population.

Efforts to remediate and prevent environmental damage lead to increases in taxes and other costs of doing business in the private sector. Generally, these environmental expenditures carry an opportunity cost: if the natural ecosystem did not require remediation, public and private monies would have been spent in more productive ways.

Violations of environmental standards have resulted in increased government regulation, with its associated costs. The federal government, through the EPA, has required that local-area governments take steps to improve air and water quality. If standards are not achieved, the EPA has the authority to restrict industrial activities in Central Arizona, affecting the growth of the area.

In the Phoenix area, differentially increasing damage to the natural ecosystem, and rising costs to mitigate such damages, at some point could add up to a local competitive disadvantage which could make economic development more difficult. Net business expansion could slow as more local companies leave and fewer new companies locate in the affected area. Similarly, real and perceived reductions in the quality of life could cause fewer individuals to move to the area and as well as an increase in the number of local residents leaving.

Physical And Biological Alterations To Ecosystems

The natural environment has ecological, psychological, sociologic and economic values to humans. Some ecological functions include nutrient cycling, energy-flow processes, breakdown of toxics, conversion of carbon dioxide to oxygen, and the capture of solar energy through photosynthesis. The biological and physical attributes of ecosystems contribute to environmental health and integrity, which are essential to human survival. Psychological studies show that stressed individuals and surgical patients recover faster when allowed to view nature scenes.

TABLE 8
QUALITY-OF-LIFE RATINGS

	Criteria*							
Issues	Summary	Economic	Social	Future	Aesthetics	PeaceMind	Recreation	Uncertainty
Air Pollution	H	H	L	L	L	H	M	L
Alteration of Ecosystems	H	H	M	H	M	M	M	L
Surface Water Contamination	M	M	M	M-H	M	M	M	L
Groundwater Contamination	M	M	M	H	—	M	L	L
Food and Water Contamination	M	M	M	M	M	M-H	L	L
Land and Soil Contamination	L	M	M	M	L	M-H	L	M
Accidental Releases	L	L	H	L	L	M	L	H
Radiation	L	M	L	H	L	M	L	M

H: High M: Medium L: Low

* As defined by ACERP, the criteria are

Economic impacts: present and potential damage from environmental problems.

Fairness and social impacts: correlation between the occurrence of an environmental impact and the demographics of the exposed population; and changes to the social fabric resulting from environmental issues, such as class and ethnic inequities, changes in community activism, increased community conflict, and potential struggles over limited resources.

Future-generation impacts: both short-term and long-term effects, considering the chances for restoration.

Aesthetics impacts: such as visual degradation, changes in comfort, distasteful smells, and damage to or loss of pleasing environment.

Peace-of-mind impacts: fears related to health impacts, contamination and ecological deterioration.

Recreational impacts: damage and loss of access to recreational areas.

Uncertainty.

Source: Arizona Comparative Environmental Risk Project, Quality-of-Life Committee.

Natural areas provide direct benefits to recreationists and increase recreation-related spending in local economies. Streamflows provide water-quality benefits to downstream entities such as cities and farms, reducing water treatment expenses.

In addition, some individuals who do not directly use a site still benefit from natural areas and streams. They value leaving the environment in its natural state to pursuing an irreversible alternative and are willing to pay so that future generations can enjoy the preserved ecosystem.

The recognition of negative or potential harmful effects of human activities on the natural ecosystem has led to mandatory economic impact studies prior to some types of development. If the study does not result in stopping or altering the project, it slows down the process and adds to the cost. For example, the Endangered Species Act could lead to restrictions on development.

Sensitivity to pollen from non-native plants reduces personal quality of life. It also causes more resources to be put into health care and leads to more sick time being taken, lowering business efficiency. Retired farmland, with its weed growth and dust, contributes to the problem. Disturbances to the soil release the cocci fungus, which causes valley fever.

The perceived quality of life also can suffer as attractive natural areas are lost to development. ACERP assessed the physical and biological alteration of ecosystems to have high economic and future-generation impacts. Fairness and social impacts were rated as moderate, as were the effects on aesthetics, peace of mind and recreation.

In addition to natural ecosystems, the ACERP study designated agriculture as an ecosystem. This man-made ecosystem is most threatened by pumping and urbanization, with species introduction and land and soil contamination also factors. The increasing cost of water is a major threat to the economic viability of farming in Central Arizona.

Land and Soil Contamination

Health risks and associated costs can result from land and soil contamination, such as from pesticides. The risks and costs are most apparent when residential development is considered for contaminated sites. Other business costs include those of cleaning a contaminated area and switching from the use of a banned chemical to a substitute. Because of the risks and disamenities associated with landfills, the public has made siting new landfills a lengthy and difficult process, adding to the cost.

ACERP rated the effects of land and soil contamination to be medium to high in the peace-of-mind category and medium in the economic, fairness, future generations and uncertainty categories. Leaking underground storage tanks were designated as a low risk to human health.

Water Quality

Human impacts on water quality have led to increased costs of water treatment. Increased salinization has costly consequences. Some chemicals, such as some pesticides, have been banned because of their effects on water quality. Bioaccumulation of toxic compounds through the food chain can have severe consequences for humans.

Groundwater and surface water contamination were assessed by ACERP as having high impacts on future generations. Surface water contamination was considered to have moderate effects in the categories of economics, fairness, aesthetics, peace of mind and recreation. Groundwater contamination was considered of moderate importance in the fairness and peace-of-mind categories. ACERP's human health committee rated the risk from superfund sites as low.

Drinking water contamination was assessed as having a medium-to-high effect on peace of mind. Contamination of drinking water was rated as having medium impacts on economics,

fairness, future generations and aesthetics. The Arizona Department of Water Resources estimates that in each year from 1993 through 1997 more than one million Phoenix area residents used water from a community water system that had one or more violations of EPA standards.

Questions about water quality, and the frequently poor taste of Phoenix area water, have led many residents to spend substantially on what previously was a nearly free resource. Poor water quality may contribute to inadequate water consumption by some visitors and residents.

Water Quantity

Worldwide, agriculture consumes 70 percent of the water used by humans. The figure in the Phoenix Active Management Area (AMA) was 70 percent in the mid-1980s, but by the mid-1990s it had dropped below 60 percent. Municipal use has reached 40 percent of total water use in the AMA, with industrial use not quite 5 percent. When urbanization replaces farms, considerably less water typically is used for the same acreage. However, most of the growth of the Phoenix urbanized area has been onto rangeland or unused land. Thus, total water use in the Phoenix AMA has dropped only a little, a result of a small decline in per capita water demand.

The arrival of CAP water in the late 1980s resulted in local surface water and groundwater use to be scaled back by each category of water user: agricultural, industrial and especially municipal. Effluent has been used for more municipal and industrial applications, but still provides only 5 percent of the total water used. Nearly 90 percent of water used by agriculture comes from an equal split between groundwater and local surface water. In municipalities, the groundwater share is only 30 percent, with CAP and effluent accounting for 25 percent. The much smaller industrial category gets 85 percent of its supply from groundwater.

Human use of water has led to a variety of feedbacks on human activities. The legal system regarding water rights is complex, leading to increased costs of doing business. Continued growth and overutilization of existing surface and underground water has led to very expensive solutions, such as the Central Arizona Project.

Land subsidence due to overpumping results in extra expense and restrictions to development in affected areas. If subsidence proceeds too long, the ability of the underlying soil to accept recharge water can be compromised. Subsidence also can lead to changes in water flows, possibly resulting in floods.

Various restrictions or increased costs of water use may occur, affecting agriculture, urban landscaping, heavy water-use industries, and patterns of future development.

Air Quality

Poor air quality has led to health risks, added health costs and an increase in illness with associated greater use of sick leave. Poor air quality caused 31 percent of Phoenix area residents to restrict their outdoor activities, according to the 1998 Morrison Institute survey. By lowering the quality of life, air pollution may lead to reductions in tourism and business attraction.

Other costs related to air pollution include vehicle emissions testing (required by the EPA), other monitoring, abatement procedures, and other business costs. Air pollution has a negative impact on agriculture, particularly on vegetable and cotton growers from ozone.

Continued poor air quality may lead to bans or restrictions on human activities, such as the use of fireplaces, lawn mowers and other gasoline-powered tools, and drive-through lanes. Industry activity could be reduced mandatorily during periods of high pollution. Further, the EPA has the power to ban new sources of pollution, leading to reduced growth in the Phoenix area.

ACERP considered air pollution in urban areas to have high economic and peace-of-mind

effects and a medium recreational impact. Air pollution in rural areas was deemed to have a medium impact on social and equity issues, economics, and peace of mind.

Effects of Individual Pollutants

Carbon monoxide is absorbed through the lungs into the bloodstream, where it reduces the ability to carry oxygen. Low-level exposure leads to headaches, dizziness, fatigue and reduced mental abilities. Long-term exposure results in a higher incidence of heart disease. The combination of carbon monoxide and noise damages hearing more than noise alone.

Ground level ozone, which has a sharp, pungent odor, has serious health effects including worsening the breathing problems of asthmatics. Ozone scars tissue, increases the incidence of infection in healthy lungs, and can impair the immune system. High incidences of ozone cause many people to restrict their activities. Ozone was assessed a medium risk by the ACERP human health committee.

Nitrogen dioxide has an offensive odor and causes eye irritation and increased susceptibility to lung disease. Some hydrocarbons are carcinogenic. The brown haze from smog is estimated to lower property values in the more affected areas. Smog can cause respiratory tracts to be more susceptible to valley fever.

Particulates cause a number of premature deaths and substantial expenditures on health care. The human health committee of ACERP rated fine particulates, allergens and valley fever to be high risks. Hazardous air pollutants were given a medium risk.

Other

Noise pollution, sight pollution, climatic impacts, and similar consequences of human actions may lead to reductions in the perceived quality of life. Warmer summer nights lead to increased power usage during the peak season.

Radiation and UV rays may lead to increased health risks and expenses. Radiation was considered to have medium impacts on economics, peace of mind and uncertainty by ACERP.

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