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An evaluation of sand and gravel resources in and near the Verde Valley of the Coconino National Forest, Arizona

by

Leslie J. Cox[1]

Open-File Report 95-31

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[1] U.S. Geological Survey, Univ. of Ariz., Gould-Simpson Bldg. #77 Rm 406, Tucson, AZ 85721

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CONTENTS

EXECUTIVE SUMMARY

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GENERAL

- The Verde Valley of the Coconino National Forest is an area with numerous, isolated, small or of otherwise marginal quality, sedimentary and alluvial deposits that could be utilized as sand and gravel resources.
- The identification and evaluation of sand and gravel resources was facilitated by the availability of recent large scale maps of Quaternary geology.
- Six sand and gravel tracts are recognized, in addition to the sand and gravel in the active channels of the Verde River and its perennial tributaries.

ABSTRACT

This evaluation of the Verde Valley and adjacent areas in the Coconino National Forest provides the land managers of the U.S. Forest Service with a map, on a U.S. Forest Service 1:126,720 base, of six tracts that contain geologic units that are sand- and gravel-bearing and one tract that contains aggregate-source occurrences. In addition, the qualities of sand and gravel in the active channels of the Verde River and its perennial tributaries are described. The map distinguishes (1) sand- and gravel-bearing units that are limited to channels from those that are not, (2) sand- and gravel-bearing units that are thin (generally less than 40 feet thick which is one contour interval on the topographic maps) from those that are locally thick (generally 40 feet or more), (3) sand- and gravel-bearing units that are poorly sorted from those that are well-sorted, (4) sand- and gravel-bearing units that contain unique (for the area) clast-lithologies from those that contain common (for the area) clast lithologies, (5) and sand- and gravel-bearing units that support riparian vegetation from those that do not. These distinctive characteristics are related to the geologic age or depositional setting of the rock materials and can be distinguished where areas are mapped in detail. This report also serves as a guide to areas where detailed mapping is still needed in order to make a uniform evaluation.

INTRODUCTION

Location and Physiography

The Verde Valley is in central Arizona (fig. 1). The valley is one of several northwest-trending basins in the Transition Zone geological province in Arizona (House and Pearthree, 1993, p. 12). An excellent brief history of the human inhabitation of the valley was summarized in Twenter and Metzger (1963, p. 5-11).

The Verde River flows through the Verde Valley. The flow in the Verde River is perennial and is sustained by ground water from numerous springs (Twenter and Metzger, 1962, p. 1). The eastern tributaries to the Verde River, including West Clear, Beaver, Oak, and Sycamore Creeks, drain the Mogollon Rim, a prominent escarpment marking the

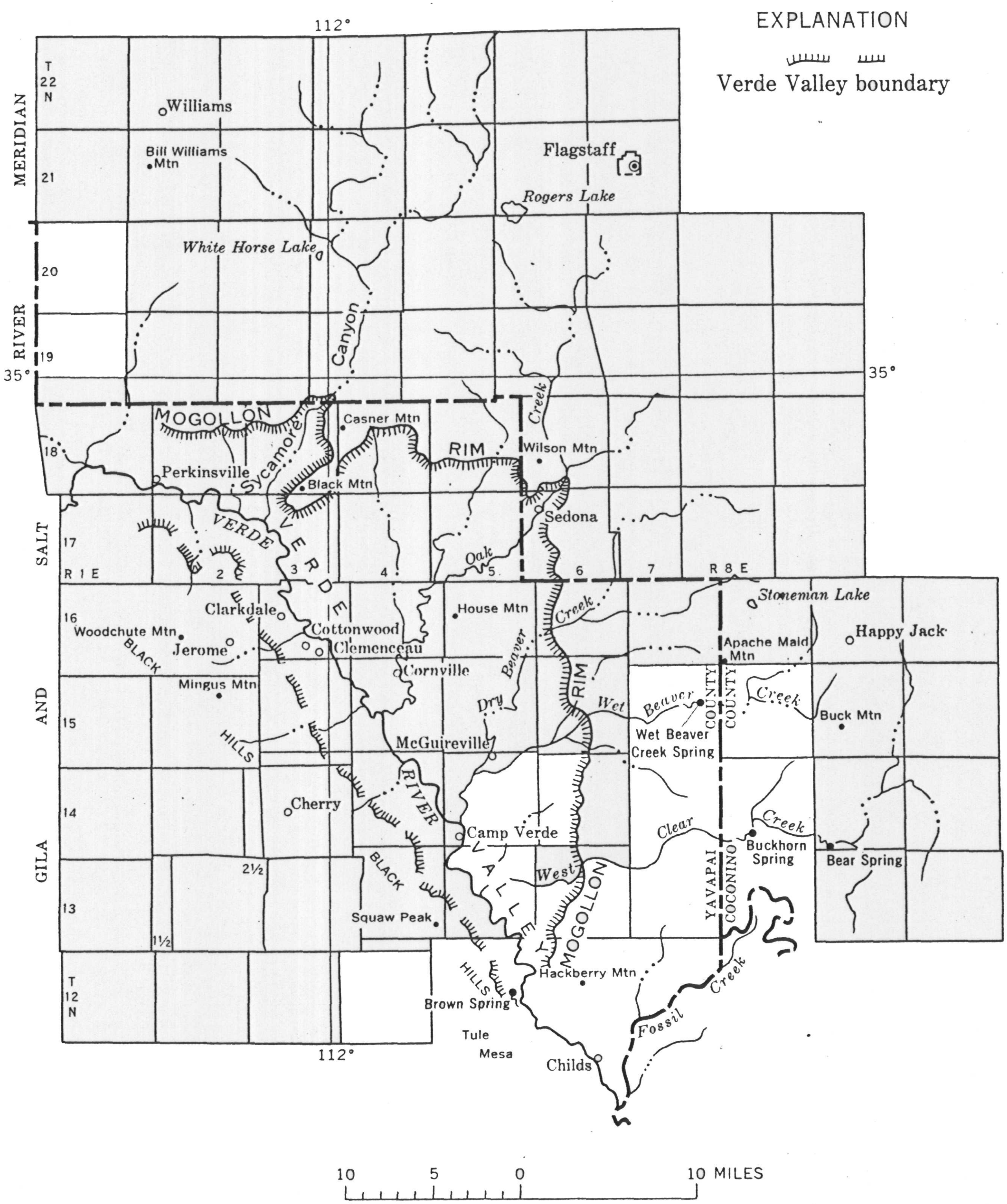

Figure 1. Index map showing the location of the Verde Valley, Yavapai and Coconino Counties, Arizona, taken from Twenter and Metzger, 1963, p.6.

southern edge of the Colorado Plateau (House and Pearthree, 1993, p. 12) that rises abruptly 1,000 to 2,000 ft above the valley floor (Twenter and Metzger, 1963, p. 5) on the north and east sides of the valley. On the southwest, the Verde Valley is bounded by a northwest-trending range, the Black Hills, which rise 1,000-3,000 ft above the valley floor.

Exposed along the Mogollon Rim are the Kaibab Formation, Toroweap Formation, Coconino Sandstone, and Supai Formation, all of Paleozoic age ranging from Lower Permian to Upper Pennsylvanian. Also exposed along the rim are Tertiary volcanic rocks and the sedimentary rocks of the Verde Formation. Exposed in the Black Hills are Precambrian rocks, Paleozoic rocks ranging in age from Lower Permian to Cambrian, Tertiary volcanic rocks, and the Verde Formation.

Purpose of Evaluation

The purpose of this evaluation of the Verde Valley and adjacent areas of the Coconino National Forest is to provide geologic information, on a U.S. Forest Service base[1], that may be of use to land managers in making decisions regarding present and future sand and gravel resource development. The distribution of surficial and sedimentary deposits of a wide variety of size and quality were investigated to insure reasonable completeness.

This report used the most detailed geologic maps available to demonstrate the relationships between geologic age, depositional setting, expected quality, and present-day distribution of sand- and gravel-bearing units. This report also identifies areas that should be mapped in greater detail.

Previous Investigations

Lane (1992) identified several areas in the Coconino National Forest as having moderate development potential for sand and gravel resources. He reported that many sand and gravel deposits exist as isolated pockets throughout the area, most of the deposits are found in the drainages, and the larger deposits occur along the Verde River. He also noted that most of the sand and gravel presently mined is on private land (Lane, 1992, p. 42).

Pearthree (1993), House and Pearthree (1993), and House (1994) studied the geology and geomorphology of the central Verde River and prepared detailed maps of the surficial alluvial deposits of the Verde River and its tributaries. Their work defined the physical framework in which the riparian environments along the river exist (Pearthree, 1993, p. 3).

Acknowledgments

Indispensable to my study, and not available to the earlier work by Lane (1992), are the detailed maps of the surficial geology of the northern Verde Valley by P.A. Pearthree

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[1] U.S.F.S. base is a polyconic projection of roads, township and section lines, and other geographic features at the scale of 1:126,720.

and P.K. House of the Arizona Geological Survey (see fig. 2 -- Index of maps). My study utilized the hierarchy of age established in Pearthree (1993) and House and Pearthree (1993) and benefited significantly from my discussions with them about the Quaternary geology of the area.

Appreciation is also expressed to J.D. Bliss and G.J. Orris of the U.S. Geological Survey who provided maps, articles, MRDS records, and other useful information; to E.M. Matthews of the U.S. Forest Service who provided priority guidance and permitted my use of color aerial photographs of the Forest; and to T.F. Harms and C. Bramley of the U.S. Geological Survey who provided assistance during field work conducted in July, 1994.

EVALUATION OF THE POTENTIAL FOR SAND AND GRAVEL RESOURCES

General Geologic History

Sand and gravel resources have been exploited in the Verde Valley from geologic units ranging in age from early Miocene to modern. The general geologic history of the area during this time is as follows:

Tertiary Period

early Miocene and older to late Miocene (24 Ma to about 8 Ma) Stream, lake, and fan deposits of several generations and different source areas were deposited unconformably on uneven, locally markedly channeled surfaces that truncate Mesozoic and Paleozoic rocks (Weir and others, 1989).

late Miocene (about 8 Ma to 5 Ma) Stream, lake, and fan deposits, interbedded with lava flows, began to accumulate in a basin whose external drainage was probably blocked at the southern margin by structural subsidence and volcanic activity (*after* Bressler and Butler, 1978, and McKee and Elston, 1980, as cited by House and Pearthree, 1993, p. 12).

Pliocene (5 Ma to 2 Ma) The basin-filling sediments reached their highest level by 2 to 2.5 Ma (House and Pearthree, 1993, p. 4). Basin accumulation ended and basin dissection began when the Verde River breached the southeast end of the valley (*after* Bressler and Butler, 1978, and Nations and others, 1981, as cited by House and Pearthree, 1993, p. 12).

Quaternary Period

Pleistocene (2 Ma to 10 ka) Basin dissection and downcutting by streams continued into the Quaternary, possibly in response to regional uplift of the Transition Zone (*after* Péwé, 1978, and Menges and Pearthree, 1989, as cited by House and Pearthree, 1993, p. 13). Erosion-resistant coarse gravels were deposited in piedmont alluvial fans and in the terraces of major streams.

Figure 2. Index to geologic maps and U.S. Geological Survey topographic maps of the Verde Valley, Yavapai and Coconino Counties, Arizona.

EXPLANATION

-- —— -- County lines

——————— Interstate Highway 17, State Highway 79

——————— Coconino National Forest boundary

DUGAS 7.5-minute quadrangle

SOURCES OF GEOLOGIC DATA

1 House and Pearthree, 1993, CLARKDALE 7.5' QUADRANGLE

2 House and Pearthree, 1993, PAGE SPRINGS 7.5' QUADRANGLE

3 House and Pearthree, 1993, COTTONWOOD 7.5' QUADRANGLE

4 House and Pearthree, 1993, CORNVILLE 7.5' QUADRANGLE

5 Pearthree, 1993, Sullivan Lake to Horseshoe Resevoir at scale 1:24,000

6 Lehner, 1958, CLARKDALE 15' QUADRANGLE

7 Weir and others, 1989, SEDONA 30' X 60' QUADRANGLE

8 House, 1994, MIDDLE VERDE 7.5'QUADRANGLE

9 House, 1994, CAMP VERDE 7.5'QUADRANGLE

10 House, 1994, HORNER MTN 7.5'QUADRANGLE

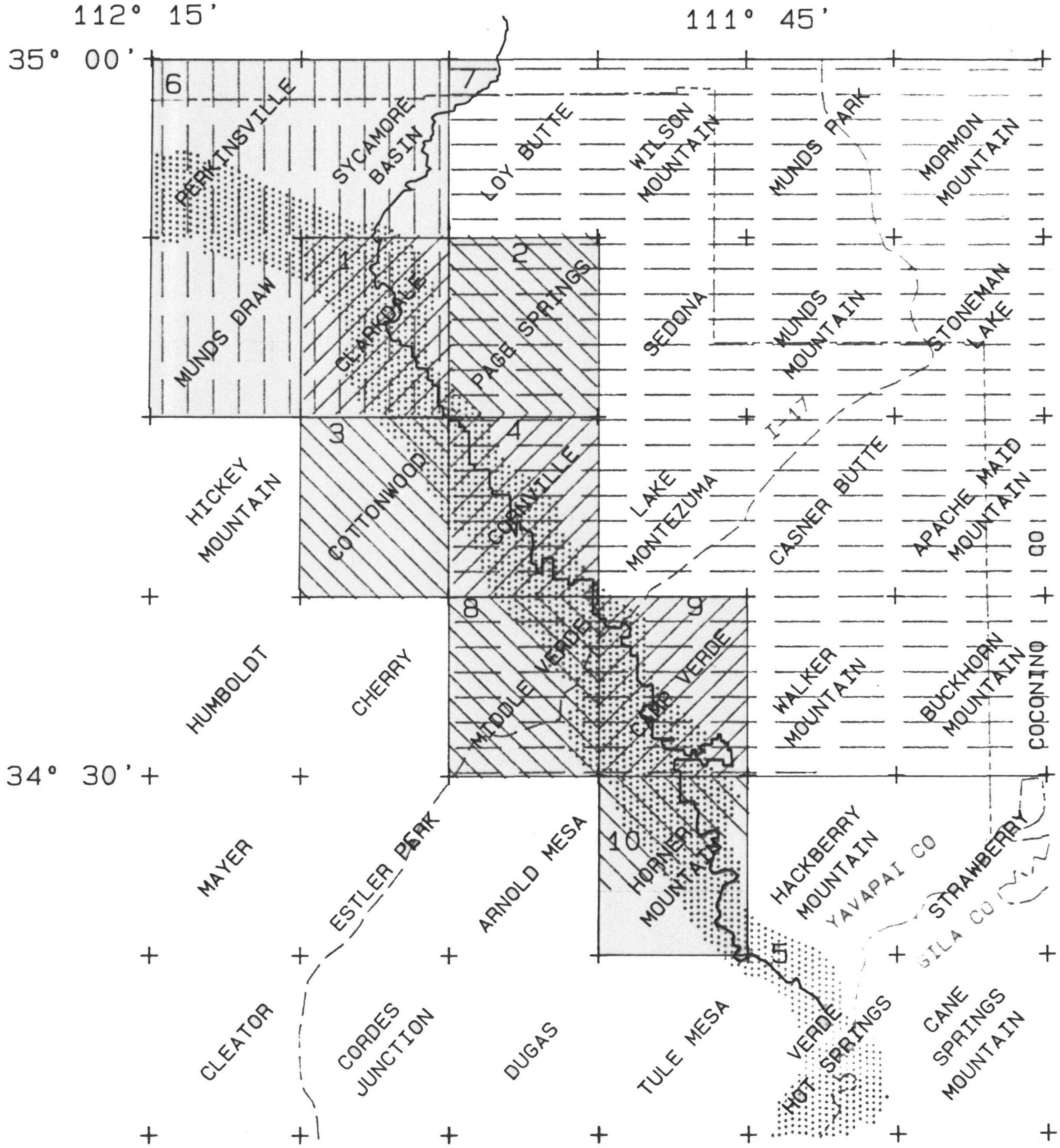


Figure 2. Index to geologic maps and U.S. Geological Survey topographic maps of the Verde Valley, Yavapai and Coconino Counties, Arizona.

Holocene (10 ka to <a few thousand years) Erosion resistant coarse gravels were deposited in young piedmont alluvial fans and low terraces along piedmont and ephemeral drainage courses (House and Pearthree, 1993).

late Holocene (<a few thousand years) Silt, sand, gravel, and cobbles are deposited in the active flood plains and channels of major streams during a time that may represent the deepest level of incision reached in the valley during the Quaternary (House and Pearthree, 1993, p. 17).

In summary, the history of the Verde Valley is one of basin accumulation or aggradation, mostly in the Tertiary period, followed predominately by dissection or degradation in the Quaternary period. Aggradation resulted in broadly distributed, interfingered facies of materials that had been eroded from the surrounding highlands and deposited in the basin as sediments in lakes, alluvial plains, and alluvial fans. Sand and gravel occur in the alluvial-fan facies which are, in the case of the Verde Formation, generally located at the margins of the basin in which they were deposited. The subsequent, overall, degradation of the Verde basin resulted in geomorphically defined, alluvial-fan and stream deposits that consist of reworked basin-fill sediments as well as new material eroded from the present-day highlands. Sand and gravel occur in alluvial-fan remnants, thin alluvial fans, and stream deposits whose positions relative to (and heights above) the Verde River and its major tributaries are a function of their age (the time of abandonment of the geomorphic surface).

Rationale for Depiction of Tracts

Clast composition, thickness, degree of sorting, the degree of weathering, and the extent and distribution of mappable units are some of the characteristics related to the geologic age (Tertiary, Quaternary) or depositional setting (aggradational, degradational, alluvial fan, stream terrace) of alluvial materials. The differences in these characteristics (i.e. well sorted versus poorly sorted; major soil development versus minor soil development) make it desirable to group sedimentary and alluvial materials with shared characteristics. Such a group is here called a tract. Although each tract consists of several geographically separated islands, the descriptions and evaluations of each tract that follow refer to the sum total of the area covered by the islands.

Classification of resource potential follows the definitions of Goudarzi (1984).

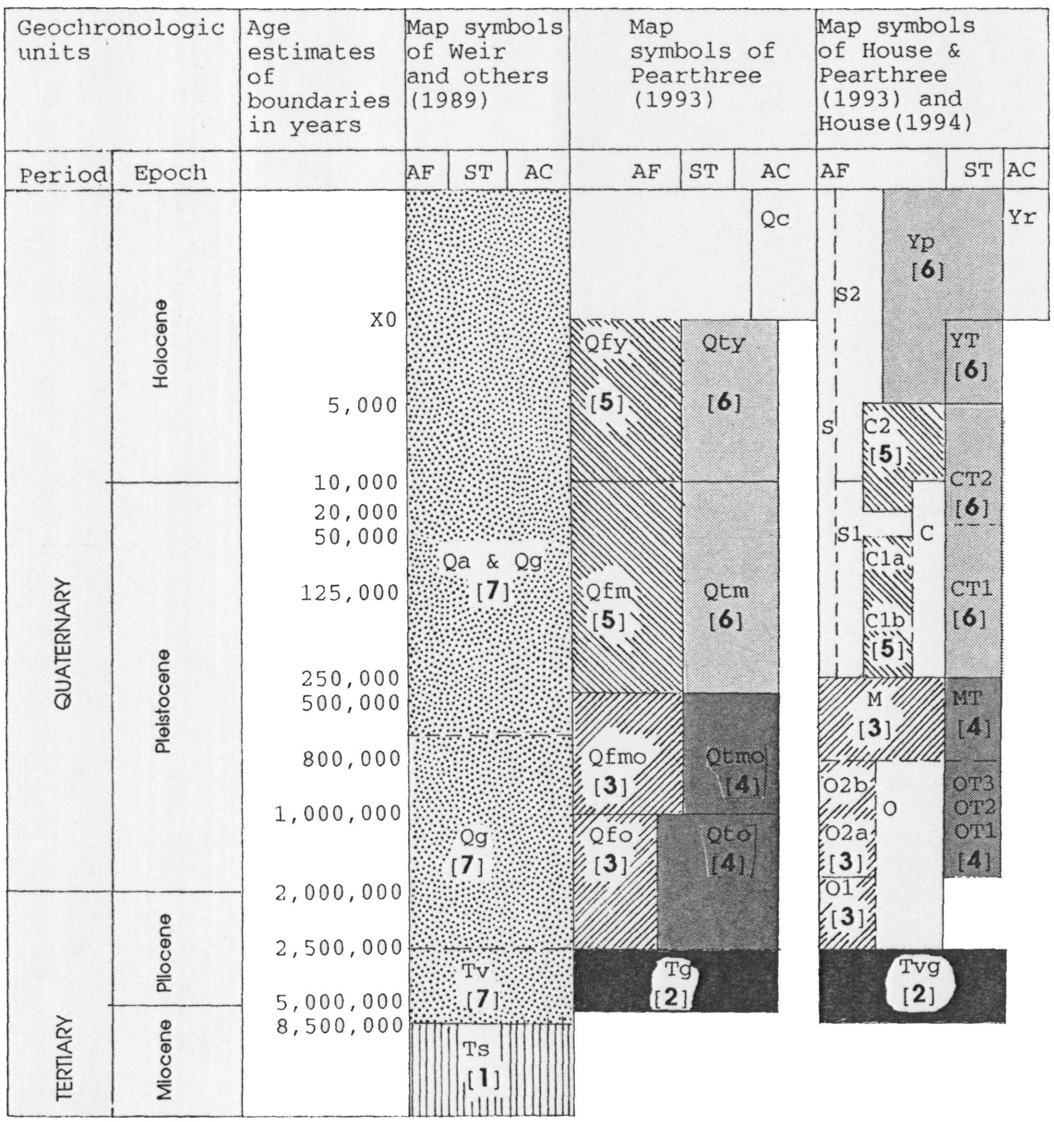
Description of Tracts

Six tracts are shown in plate 1. The active channel deposits of the Verde River and its perennial tributaries are not delineated on plate 1 but are instead described below.

The alluvial and stream deposits remain undivided (7) (pl. 1 and table 1) where the detail of available geologic maps does not support separation of alluvial and stream deposits into tracts. The area labeled "7" is based on the geologic units "Qa" and "Qg" of Weir

Table 1. Stratigraphic table showing varied map symbols used for the same rock units and the correlation of these map symbols to the labels used in this report for the tracts permissive for the occurrence of sand and gravel resources in the Verde Valley, Yavapai and Coconino Counties, Arizona.

[Column head abbreviations are: AF, Alluvial Fan; ST, Stream Terrace; and AC, Active Channel. Beneath the correlative map symbols, the tract labels in square brackets are: **7**, Undivided; **6**, Young stream terraces; **5**, Young alluvial fans; **4**, Old stream terraces; **3**, Old alluvial fans; **2**, Basin-fill gravels; and **1**, Sedimentary rocks of Tertiary age. Map symbols of Weir and others (1989) are: Qa, Alluvium; Qg, Gravel; Tv, Verde Formation; Ts, Sedimentary rocks. Map symbols of Pearthree (1993) are: Qc, Deposits of active channels of the Verde River and major tributaries; Qty, Low terraces of the Verde River and major tributaries; Qfy, Channels and low terraces of tributary streams; Qtm, Mid-level terraces of the Verde River and major tributaries; Qfm, Mid-level terraces and alluvial fans associated with tributaries of the Verde River; Qtmo, Older mid-level terraces of the Verde River and major tributaries; Qfmo, Older mid-level terraces and alluvial fans associated with tributaries of the Verde River; Qto, Very high terraces of the Verde River and major tributaries; Qfo, Very high alluvial fans of tributaries to the Verde River; Tg, Basin-fill sediments. Map symbols of House and Pearthree (1993) and House (1994) are: Yp, Young piedmont alluvium; Yr, Active channels of major streams; YT, Young terraces; S,S1, and S2, Sheepshead Group; C,C1a,C1b, and C2, Chuckwalla Group; CT1 and CT2, Chuckwalla Terraces; M, Montezuma alluvial fan complex; MT, Montezuma Terraces; O, O1, O2a, and O2b, Oxbow Group; OT1, OT2, and OT3, Oxbow Terraces; Tvg, gravel facies of Verde Formation]



and others (1989). In the Loy Butte quadrangle, some revision of "Qg" (Weir and others, 1989) was accomplished by reconnaissance field observations of selected contacts and subsequent interpretation of color aerial photographs whose scales were 1:19,200 and 1:16,560.

No tracts were drawn in the area of the Hackberry Moutain quadrangle where geologic maps of alluvium are presently not available (fig.2).

Some characteristics of the tracts are summarized in table 2. Detailed descriptions of the quality, quantity, and distribution are given in the text that follows.

Tract Characteristics	Tract 1	Tract 2	Tract 3	Tract 4	Tract 5	Tract 6
RESTRICTED TO CHANNEL						X
SUPPORTS RIPARIAN VEGETATION					X	X
LITTLE SOIL DEVELOPED					X	X
WELL SORTED TERRACE				X		X
THIN (< 40 FT)				X	X	X
LOCAL CLAST LITHOLOGIES		X	X	X	X	X
POORLY SORTED FAN	X	X	X		X	
NOT RESTRICTED TO CHANNEL	X	X	X	X	X	
SUPPORTS NON-RIPARIAN VEGETATION	X	X	X	X		
LOCALLY > 40 FT THICK	X	X	X			
MAJOR SOIL OR LITHIFICATION	X	X				
EXOTIC CLAST LITHOLOGIES	X					

Table 2. A comparison of the characteristics of sand and gravel tracts in the Verde Valley, Yavapai and Coconino Counties, Arizona.

[TRACT 1] TRACT OF SEDIMENTARY ROCKS OF MIOCENE OR OLDER TERTIARY AGE

Description This tract chiefly contains semi-consolidated to well indurated conglomerates with interbeds of sandstone, mudstone, and limestone (Weir and others, 1989) that are probably more than 8 Ma. Some of the deposits contained within this tract probably include the rim gravels described by Peirce and others (1979), Peirce and Nations (1986), and the Hickey Formation of Levings (1980). The pebbles and cobbles in the conglomerate are well rounded and composed of Precambrian igneous and metamorphic rocks derived primarily from terranes located south of 34° 30' of latitude and (or) resistant Paleozoic rocks, chiefly the Kaibab Formation and the Coconino Sandstone from the plateau on the north (Weir and others, 1989).

Descriptions of known workings Two abandoned borrow pits are located in the SE¼ sec. 35, T. 16 N., R. 5 E. and the NW¼ sec. 2, T. 15 N., R. 5 E., of the Lake Montezuma quadrangle. The exploited material was likely the loose colluvial gravel that has weathered or been excavated from a colorful medium pebble gravel conglomerate composed of metavolcanic, sandstone, and limestone pebbles. Outcrops of the consolidated rock have sand-sized reddish brown (10R5/6) matrix. The conglomerate lies beneath outcrops of younger basalt and here contains no clasts of basalt.

Rationale for tract type
(1) Lithology The clast composition differs from all of the younger clastic and surficial deposits in the area because a) the units were deposited mostly before extensive, regional, basaltic volcanism and, therefore, lack basalt gravels, except locally, and b) igneous and metamorphic rocks of Proterozoic age were more widely exposed in the highlands as sources for gravel at the time of sedimentation.

(2) Distribution Unlike the youngest surficial materials of Quaternary age, these sedimentary rocks are not confined to modern stream channels. Although these rocks undoubtedly lie beneath the younger basalt cover, only those parts exposed to weathering have been exploited.

(3) Thickness The beds are discontinuous but in places are quite thick; generally less than 50 ft but as much as 360 ft thick (Weir and others, 1989).

Method of tract delineation Because no published geologic maps distinguish the sandstone and conglomerate facies from mudstone and limestone, all units mapped by Lehner (1958) and Weir and others (1989) as sedimentary rocks of Miocene or older Tertiary age, undivided, are shown on plate 1.

Recommendations for future work The conglomerates and sandstones should be mapped separately from the finer grained facies of the units shown as Miocene or older Tertiary sedimentary rocks by Lehner (1958) and Weir and others (1989). Conglomerates with basalt cobbles should be delineated from those which do not have basalt cobbles. Units that are extremely well consolidated should be delineated from those that are loosely consolidated.

Resource potential This tract has moderate potential for aggregate resources that might be obtained from the conglomerates and sandstones. The material is locally thick and has been a historical source of aggregate.

[TRACT 2] TRACT OF THE BASIN-FILL GRAVEL FACIES OF THE VERDE FORMATION OF LATE MIOCENE AND PLIOCENE AGE

Description This tract contains alluvial fan materials of about 2.5 Ma, but possibly as old as 8.5 Ma. The fans consist of very poorly sorted coarse gravels and cobbles of diverse lithologies (House and Pearthree, 1993). Paleozoic sandstones and Tertiary basalts are the predominant clast lithologies. Particle sizes range from silt and sand to boulders, and clasts are typically subangular (House and Pearthree, 1993).

Description of known working An abandoned borrow pit is located in the NE¼ sec. 20, T. 17 N., R. 5 E., of the Sedona quadrangle. The unconsolidated materials exploited from the borrow pit range from silt to boulder gravel in size. The gravels are composed mostly of Paleozoic sandstone, chert, and limestone of various shades of red, yellow, and white, and of gray Tertiary basalt. The cobble gravel is fairly, but not completely, free of coatings of calcium carbonate or clay. Exposed by excavation are several ledges of well consolidated, poorly sorted conglomerate with a silty-sandstone matrix around clasts that range from very angular basalt gravels (in great abundance locally) to well-rounded boulders of Paleozoic sandstone. The deposit is only about 200 ft above Dry Creek and is capped by alluvial fan material that is about 270 ft above Dry Creek. The exploited material may be a gravel facies of the Verde Formation.

Rationale for tract type
(1) Distribution In many places these gravels occur as rounded, high-standing hillocks (House and Pearthree, 1993, p. 11) between, rather than within stream channels at the margin of the Verde Valley.

(2) Sorting and thickness These gravels are very poorly sorted but are generally greater than 40 ft thick.

(3) Soil development Soil is strongly developed.

Method of tract delineation This tract contains the gravel facies of the Verde Formation as mapped by Lehner (1958, unit Qtvg) and by House & Pearthree (1993, unit Tvg). Although Weir and others (1989) recognized that the oldest gravels flanking the Verde Valley might be late Pliocene (Tertiary) in age, they chose not to show them separately from the younger terrace and alluvial-fan deposits of Quaternary ages (unit Qg).

Recommendations for future work The gravel facies of the Verde Formation should be mapped separately from the younger alluvial-fan, stream-terrace, and active-channel deposits presently represented by the map unit "Qg" on the geologic map of the Sedona 30' X 60' quadrangle by Weir and others (1989).

Resource potential This tract has low potential for sand and gravel resources in alluvial fan materials. Negative attributes include strong soil development and poorly sorted material. A positive attribute is local thickness in excess of 40 ft.

[Tract 3] TRACT OF HIGH ALLUVIAL FANS OF LATE PLIOCENE TO MIDDLE PLEISTOCENE AGE

Description This tract contains the alluvial fans that are about 0.5 to 2.5 Ma (Pearthree, 1993, p. 9-10, and House and Pearthree, 1993, p. 5). The highest and oldest fans generally rest on surfaces eroded into either the Verde Formation or Paleozoic units and locally grade gradually downward into the coarse fan facies of the Verde formation (Pearthree, 1993, p. 10). These alluvial fans typically are found 80 to 490 ft above modern drainages (House and Pearthree, 1993, p.3 and 5) and comprise the thickest Quaternary deposits in the northern Verde Valley, however the local variation in thickness is considerable (House and Pearthree, 1993, p. 5). These fans typically consist of poorly sorted silt to gravel (Pearthree, 1993, p. 9-10).

Description of known working An abandoned gravel pit is located in the NW¼ sec. 16, T. 17 N., R. 5 E., of the Sedona quadrangle. The gravel pit is more than 260 ft above the modern channel of Dry Creek and has been excavated to a depth of at least 40 ft. The exploited material ranges from silt to boulder gravel in size. The gravels are composed mostly of Paleozoic sandstone, chert, and limestone of various shades of red, yellow, and white, and of gray Tertiary basalt. The cobble gravel is fairly, but not completely, free of coatings of calcium carbonate or clay. The silt and sand materials are pale moderate brown (5YR4/3). Field inspection of this deposit indicated that at least part of it is probably a member of the Oxbow Group of Pearthree (1993) and House and Pearthree (1993), therefore, although its character and age cannot be determined from the available geologic maps, it is described as an example of this tract type.

Rationale for tract type
(1) Sorting and thickness The high alluvial fans are typically thicker and less well sorted than correlative stream terraces. The oldest high alluvial fans are typically very poorly sorted and relatively thin (<33 ft thick) (House and Pearthree, 1993), however, they can be quite thick. In the Loy Butte quadrangle, alluvial-fan deposits are as much as 100 ft thick.

(2) Distribution These alluvial fans were abandoned at levels higher above the modern channels than the younger alluvial fans (tract described below) and are generally not restricted to the interiors of narrow canyon reaches.

(3) Soil development Clay horizons range from strongly to moderately well developed with decreasing age. Calcic horizons range from substantially to moderately well developed (House and Pearthree, 1993, p. 5, and Pearthree, 1993, p. 10).

(4) Vegetation Although these alluvial-fan deposits have reasonable water-holding capacities, they typically are high above stream channels and, therefore, do not hold much water nor typically support riparian vegetation (Pearthree, 1993, p. 9-10).

Method of tract delineation This tract contains high, or piedmont, alluvial fans of middle Pleistocene to late Pliocene age as mapped by House and Pearthree (1993, units O, O1, O2, O2a, O2b; "O" for "Oxbow", and M); by Pearthree (1993, unit Qfo and Qfmo; "o" for "Oxbow"); and by House (1994, units O, O1, O2, O2a, O2b, and M). These piedmont alluvial fan units were mapped separately from their correlative stream terraces by Pearthree (1993), House & Pearthree (1993), and House (1994).

Recommendations for future work Map the alluvial fans that are 500,000-2,500,000 years old separately from correlative and younger stream terraces, from the younger alluvial fans, and from the active-channel deposits that are presently represented by either the map unit "Qg" or "Qa" on the geologic map of the Sedona 30' X 60' quadrangle by Weir and others (1989).

Resource potential This tract has moderate potential for sand and gravel resources in alluvial fan materials. Even though the material is generally poorly sorted, local thickness may exceed 40 ft.

[TRACT 4] TRACT OF STREAM TERRACES OF LATE PLIOCENE TO EARLY PLEISTOCENE AGE

Description This tract contains high- to mid-level stream terraces of the ages 2.5 Ma to about 0.5 Ma that were abandoned at fairly high levels above the modern stream channels and, therefore, are not restricted to the interiors of narrow canyon reaches. The terrace surfaces are typically 100 to 200 ft or more above the active channel (Pearthree, 1993, p. 9-10) but may be as high as 350 ft (House and Pearthree, p. 9). The oldest and highest stream deposits commonly consist of very coarse, well rounded cobbles and boulders, whereas the mid-level terraces are composed of the coarse gravels. Both are probably facies of channels and bars (Pearthree, 1993, p. 9-10). These terraces are usually less than 33 ft thick (Pearthree, 1993, p. 9-10).

Rationale for tract type
(1) Quality Stream terraces are typically thinner but predictably better sorted than correlative alluvial-fan deposits.

(2) Distribution These terraces were abandoned at levels higher above the modern channels than the younger terraces (tract described below) and therefore are not restricted to the interiors of narrow canyon reaches.

(3) Soil development Soil development with clay and calcium carbonate (caliche) accumulation ranges from strong to fairly strong with decreasing age (House and Pearthree, 1993, p. 9, and Pearthree, 1993, p. 9-10).

(4) Vegetation These steam terraces typically do not hold much water nor do they support riparian vegetation (Pearthree, 1993, p. 9-10).

Method of tract delineation This tract contains stream terraces that are late Pliocene to middle Pleistocene in age as mapped by Pearthree (1993, units Qto and Qtmo), House & Pearthree (1993, units OT1, OT2, OT3, and MT), and House (1994, units OT1, OT2, OT3, and MT).

Recommendations for future work The stream deposits that range in age from 0.5 to 2.5 Ma should be mapped separately from the older gravel facies of the Verde Formation, from correlative and younger alluvial fans, from the younger terraces, and from the active-channel deposits that are presently represented either by the map unit "Qg" or "Qa" on the geologic map of the Sedona 30' X 60' quadrangle by Weir and others (1989).

Resource potential This tract has low potential for sand and gravel resources in stream terrace materials. Although the material is well sorted, it is generally not very thick.

[Tract 5] TRACT OF ALLUVIAL FANS OF LATE PLEISTOCENE TO HOLOCENE AGE

Description This tract contains thin alluvial fans that are generally less than 250,000 years old (House and Pearthree, 1993, p. 6, and Pearthree, 1993, p. 9). The fans typically consist of a poorly sorted mix of silt, sand, and gravel (Pearthree, 1993, p. 8). Much of the development in the city of Cottonwood has been on 5,000-20,000 year old fans (House and Pearthree, 1993, p. 6-7).

Rationale for tract type
(1) Quality These alluvial fans are less well sorted than correlative stream terraces and thinner than the older alluvial fans (House and Pearthree, 1993, p. 6).

(2) Distribution Alluvial fans are generally not restricted to the interiors of narrow canyon reaches.

(3) Soil development Soil is minimally to moderately developed (Pearthree, 1993, p. 8-9).

(4) Vegetation Those fans that are younger than 10,000 years old typically support some riparian vegetation (Pearthree, 1993, p. 8).

Method of tract delineation This tract contains the piedmont alluvial fans of middle Pleistocene and Holocene age as mapped by Pearthree (1993, units Qfm and Qfy), House & Pearthree (1993, units C1, C1a, C1b, and C2), and House (1994, units C1, C1a, C1b, and C2).

Recommendations for future work The alluvial fans that are less than 250,000 years in age should be mapped separately from correlative and older stream terraces, from the older alluvial fans, and from active-channel deposits that are presently represented by either the map unit "Qg" or "Qa" on the geologic map of the Sedona 30' X 60' quadrangle by Weir and others (1989).

Resource potential This tract has moderate potential for sand and gravel resources in alluvial-fan materials because, though the material is generally thin, soil development is weak.

[Tract 6] TRACT OF STREAM TERRACES OF MIDDLE PLEISTOCENE TO HOLOCENE AGE

Description This tract contains the mid-level and young stream terraces that are less than 500,000 years old. These terraces are restricted to the channels of modern major streams and consist of abandoned channels and bars of coarse sand and of sand that was deposited in low velocity, slack-water areas during large floods (House and Pearthree, 1993, p. 10).

The mid-level terraces that are 5,000 to 500,000 years old (middle to late Pleistocene) are commonly much less than 16 ft thick, are 15 to 100 ft above the active channel, and are spatially separate from (located above) perennial streams and stream channels--therefore water drains out of them quite readily (Pearthree, 1993, p. 9). These mid-level terraces typically consist of the coarse gravel, are quite permeable, are fairly resistant to stream erosion, and are not inundated during large floods (Pearthree, 1993, p. 9, and House and Pearthree, 1993, p. 10).

The young stream terraces less than 5,000 years old (late Holocene) are relatively thin, are less than about 20 ft above the lowest parts of the channels, and are almost always found adjacent to the channels (House and Pearthree, 1993, p. 10).

Descriptions of known workings Two abandoned gravel pits, in the mid-level terraces of Coffee and Spring Creeks, less than 800 ft apart, are located in the SW¼ sec. 34, T. 17 N., R. 4 E., and NW¼ sec. 9, T. 16 N., R. 4 E., in the Page Springs quadrangle. The terraces are no more than 20 ft above the creek beds and consist of unconsolidated, variably sorted material ranging from silt to cobble gravel in size. The gravels are composed mostly of Paleozoic sandstone and limestone and Tertiary basalt. The cobble gravel is clean and not coated with calcium carbonate or clay. The finer material is reddish brown in color. Further up Coffee Creek the terrace beds are noticeably well sorted with zones of reddish brown sand as thick as 4 ft.

On private land less than 1 mi west of the Forest, in the young terraces and channel of the Verde River, is an abandoned gravel pit (now obscured) located in the NE¼ sec. 28, T. 16 N., R. 3 E., in the Clarkdale quadrangle.

On private land less than 0.5 mi east of the Forest is an active sand and gravel operation (Superior Sand and Gravel) in the center of sec. 14, T. 14 N., R. 4 E., in the Middle Verde quadrangle. Material seems to be from the young and mid-level terraces of the Verde River as well as from older alluvial fan material that is middle Pleistocene in age. West of the Verde River, the middle Pleistocene alluvial fans have considerable variation in thickness, reaching 80 ft locally and indicating that the alluvium may have filled irregular paleotopography carved into the Verde Formation (House, 1994, p. 6). Great thickness seems to be less common on the east side of the Verde River in the Coconino National Forest.

On private land less than 0.5 mi east of the Forest, in the active channel and young and mid-level terraces of Dry Beaver Creek, are an abandoned gravel pit and an active sand and gravel operation (B & B Materials) located in the SW and NW corners, respectively, of sec. 34, T. 15 N., R. 5 E., in the Lake Montezuma quadrangle.

Rationale for tract type

(1) Distribution The mid-level and young terraces are restricted to the interior of narrow canyon reaches (House and Pearthree, 1993, p. 9).

(2) Vegetation The mid-level terraces support some riparian vegetation; the low terraces support riparian vegetation (Pearthree, 1993, p. 8);

(3) Quality Relict channels and bars of the major stream terraces are better sorted, although thinner (<16 ft thick) than correlative alluvial-fan deposits.

(4) Soil development There is moderate to no soil development, moderate to no sediment cohesion, and no cementation (Pearthree, 1993, p. 8).

Method of tract delineation This tract contains the stream terraces of middle Pleistocene to Holocene age as mapped separately from their correlative alluvial fans by Pearthree (1993, units Qtm and Qty), House & Pearthree (1993, units CT1, CT2, YT, and YP), and House (1994, units CT1, CT2, YT, YP1, and YP2).

Recommendations for future work Map the stream terraces that range in age from modern to 0.5 Ma separately from facies of the Verde Formation, from correlative and older alluvial fans, from the older stream terraces, and from active-channel deposits that are presently represented either by the map unit "Qg" or "Qa" on the geologic map of the Sedona 30' X 60' quadrangle by Weir and others (1989).

Resource potential This tract has high potential for sand and gravel resources in stream terrace materials. Even though the material is generally thin, it is well sorted and the soil development is weak.

[not outlined] ACTIVE-CHANNEL DEPOSITS OF HOLOCENE AGE

Description The active stream beds and flood channels of the Verde River and its tributaries contain poorly sorted, relatively coarse deposits of sand, pebbles, cobbles, and boulders that are probably less than a few feet thick in all areas (Pearthree, 1993, p. 8). Flood channels include areas that convey floodwaters frequently enough to limit the development of mature riparian plant communities (House and Pearthree, 1993, p. 10). Bedrock is exposed in many of the streams.

Rationale for discussing as a tract type
(1) Distribution The active stream beds and flood channels are restricted to the Verde River and its perennial tributaries.

(2) Vegetation The active channel deposits support riparian vegetation that recovers during the periods between large floods (Pearthree, 1993, p. 8).

(3) Quality Active river deposits are generally thin and poorly sorted.

(4) Soil development There is no soil development, no sediment cohesion, and no cementation (Pearthree, 1993, p. 8).

Location The largest active channel, the Verde River, lies mostly west of the Coconino Forest. At best, half of the channel lies within the Forest boundary. The perennial streams that are lined with terraces less than 500,000 years old (see Tracts 6 and 7 on pl. 1) also contain active channel deposits. These include, but are not limited to: Oak, Spring, Coffee, Dry, Beaver, Dry Beaver, Wet Beaver, Clear, Wickiup, and Fossil Creeks.

Recommendations for future work Delineate the active channel deposits on a base that is larger in scale than the one used for this report. Units will include Qc of Pearthree (1993); Yr and parts of Yp, S, and S1 of House and Pearthree (1993) and House (1994); and parts of Qa and Qg of Weir and others (1989).

Resource potential This tract has high potential for sand and gravel resources in the active channels and in areas that convey floodwaters. Even though the material is generally thin and poorly sorted, poor sorting can be a positive attribute where soil development is absent.

CONCLUSIONS

Areas containing sand and gravel occurrences are either outlined on plate 1 or are described in the text. Analysis of recent, large scale geologic maps allowed the delineation of six tracts containing sand and gravel occurrences that share characteristics related to their geologic age and their depositional setting (Tract 1, Tract 2, Tract 3, Tract 4, Tract 5, and Tract 6). The detailed geologic maps revealed that mining along the major stream channels has utilized both alluvial-fan and terrace deposits, some of which are older than 250,000 years in age, in addition to the youngest active-channels materials.

One tract has moderate potential for aggregate resources from sandstone and conglomerate of Tertiary ages (Tract 1, pl. 1). The remaining tracts have low, moderate, and high potential for sand and gravel resources in alluvial fans and stream terrace deposits of Tertiary and Quaternary ages. Outside the areas covered by large-scale mapping, the area labeled “7” (pl. 1) contains areas of low to high potential for sand and gravel resources in alluvial fans, stream terrace deposits, and active-channel deposits, undivided.

The following can be concluded about sand and gravel resources from the descriptions of the geology of the area by Lehner (1958), Weir and others (1989), Pearthree (1993), House and Pearthree (1994), and House (1994):

--Older surficial deposits of all kinds are generally either more lithified or have greater soil development than younger surficial deposits.
--Alluvial-fan deposits are typically relatively more poorly sorted and thicker than major stream-terrace deposits.
--Young terrace deposits are generally thinner, and finer grained than older terrace deposits.
--Young terrace deposits are confined to stream channels whereas older surficial deposits of all kinds are not (see pl. 1 cross section A-A’).

--River and low terrace and low alluvial-fan deposits support riparian vegetation whereas higher terrace and alluvial-fan deposits support non-riparian vegetation.

When decisions about land-use are being made, this map of tracts may be used to optimize solutions.

REFERENCES CITED

Bressler, S.L., and Butler, R.B., 1978, Magnetostratigraphy of the late Tertiary Verde Formation, central Arizona: Earth and Planetary Science Letters, v. 38, p. 319-330.

Goudarzi, G.H., compiler, 1984, Guide to preparation of mineral survey reports on public lands: U.S. Geological Survey Open-File Report 84-787, 42 p.

House, P.K., and Pearthree, P.A., 1993, Surficial geology of the northern Verde Valley, Yavapai County, Arizona: Arizona Geological Survey Open-File Report 93-16, 19 p., 4 map sheets, scale 1:24,000.

House, P.K., 1994, Surficial geology of the southern Verde Valley, Yavapai County, Arizona: Arizona Geological Survey Open-File Report 94-23, 20 p., 3 map sheets, scale 1:24,000.

Lane, M.E., 1992, Mineral Appraisal of the Coconino National Forest, Arizona: U.S. Bureau of Mines Open-File Report MLA 11-92, 69 p., 2 appendices, 3 pls., scale 1:126,720.

Lehner, R.E., 1958, Geologic map of the Clarkdale quadrangle, Arizona: U.S. Geological Survey Bulletin 1021-N, p. 511-591, plate 45, scale 1:48,000.

Levings, G.W., 1980, Water resources in the Sedona area, Yavapai and Coconino Counties, Arizona: Arizona Water Commission Bulletin 11, 37 p.

McKee, E.H., and Elston, D.P., 1980, Reversal chronology from a 7.9- to 11.5- m.y. old volcanic sequence in central Arizona: Comparison with ocean floor polarity record: Journal of Geophysical Research, v. 85, no. B1, p. 327-338.

Menges, C.M., and Pearthree, P.A., 1989, Late Cenozoic tectonism in Arizona and its impact on regional landscape evolution, *in* Jenney, J.P., and Reynolds, S.J., eds., Geologic evolution of Arizona: Tucson, Arizona Geological society Digest 17, p. 649-680.

Nations, J.D., Hevly, R.H., Landye, J.J., and Blinn, D.W., 1981, Paleontology, paleoecology, and depositional history of the Miocene-Pliocene Verde Formation, Yavapai County, Arizona: Tucson, Arizona Geological Society Digest 13, p. 133-150.

Pearthree, P.A., 1993, Geologic and geomorphic setting of the Verde River from Sullivan Lake to Horseshoe Reservoir: Arizona Geological Survey Open-File Report 93-4, 25 p., 5 map sheets, scale 1:24,000.

Péwé, T.L., 1978, Terraces of the lower Salt River Valley, in relation to the late Cenozoic history of the Phoenix basin, *in* Burt, D.M., and Péwé, T.L., eds., Guidebook to the Geology of Central Arizona: Arizona Bureau of Geology and Mineral Technology Special Paper 2, p. 1-14.

Peirce, H.W., Damon, P.E., and Shafiqullah, Muhammad, 1979, An Oligocene(?) Colorado Plateau edge in Arizona: Tectonophysics, v. 61, p. 1-24.

Peirce, H.W., and Nations, J.D., 1986, Tectonic and paleogeographic significance of Tertiary rocks of the southern Colorado Plateau and Transition Zone, *in* Nations, J.D., Conway, C.M., Swann, G.A., eds., Geology of central northern Arizona: Field trip guidebook for Geological Society of America, Rocky Mountain Section Meeting, Flagstaff, Ariz., p. 111-124.

Twenter, F.R., and Metzger, D.G., 1963, Geology and ground water in Verde Valley-the Mogollon rim region, Arizona: U.S. Geological Survey Bulletin 1177, 132 p., plate, scale 1:62,500.

Weir, G.W., Ulrich, G.E., and Nealey, L.D., 1989, Geologic map of the Sedona 30' x 60' quadrangle, Yavapai and Coconino Counties, Arizona: U.S. Geological Survey Miscellaneous Investigations Series Map I-1896, scale 1:100,000.