6. Guidelines for tree planting and maintenance

This section contains technical information about tree planting and maintenance. Most of this information has been compiled from existing sources and includes modern standards that are widely used. Where appropriate, additional comments specific to conditions in Rocklin have been made.

6.1. Tree placement guidelines

Trees occupy space both above and below ground. Tree canopy height and spread at maturity need to be considered when trees are placed into the urban landscape around existing structures (Figure 6-1). It is normally impractical to relocate poorly placed trees after they become established. To avoid unnecessary conflicts or the need to removing established trees, the location of trees in the landscape should be carefully planned.

Distances away from structures

Above-ground clearances

City of Rocklin Improvement Standards (Section 12-8.F) specify the following minimum clearances for tree planting:

Item	Distance
City maintenance limit line	3 feet
utility installations including, but not limited to sewers, gas, water lines, meter vaults, catch basins, etc.	4 feet
driveways	10 feet
fire hydrants	10 feet
light standards	20 feet

In addition, to provide for unobstructed lines of sight, trees may not be planted in the “control area” around intersections (Section 4-10). The control areas vary with street width and geometry and are illustrated in City of Rocklin Standard Drawings 3-12 through 3-14. Section 4-26 of the Improvement Standards further states that trees shall not be planted any closer than 6 feet from the back of sidewalks adjacent to City streets.

Tree limb clearances required in section Improvement Standards Section 12-8.F.6 may also affect tree placement. Tree limbs must have a clearance of 14.5 feet over streets, 8 feet over bicycle trails, and 7 feet over pedestrian-traveled ways.

Overhead electric lines are found in some parts of Rocklin and require special attention to tree selection and placement. Only trees that have a low mature height (e.g. crape myrtle) should be planted under high voltage power lines. The height of overhead electric wires can vary, so the tree species used should be selected accordingly. The mature height of the tree should be at least 10 feet less than the height of overhead high voltage wires. In general, trees with a mature height of 25 feet or less will be safe to plant under high voltage power lines. Trees should not be planted any closer than 20 feet from utility poles.

Beyond these minimum clearances, trees should be planted far enough from buildings, sidewalks, driveways, and foundations to avoid problems. No single set of minimum clearances can be established for all species, because clearances will vary with mature tree size and tree form (e.g., spreading vs. narrow). Trees that will be large at maturity (such as

London plane) will need more room than small trees (such as crape myrtle) and should be planted farther from underground and aboveground utility lines and structures. In general, do not plant a tree closer to a building than half of its mature canopy spread (e.g., no closer than 20 feet for a tree with 40 feet spread at maturity) unless (1) the mature tree height is great enough to allow for canopy spread over the building and (2) tree canopy over the building can be tolerated. Overhanging branches shed leaves, seeds, and twigs that can clog gutters and increase maintenance needs. Large branches over buildings may be difficult to prune.

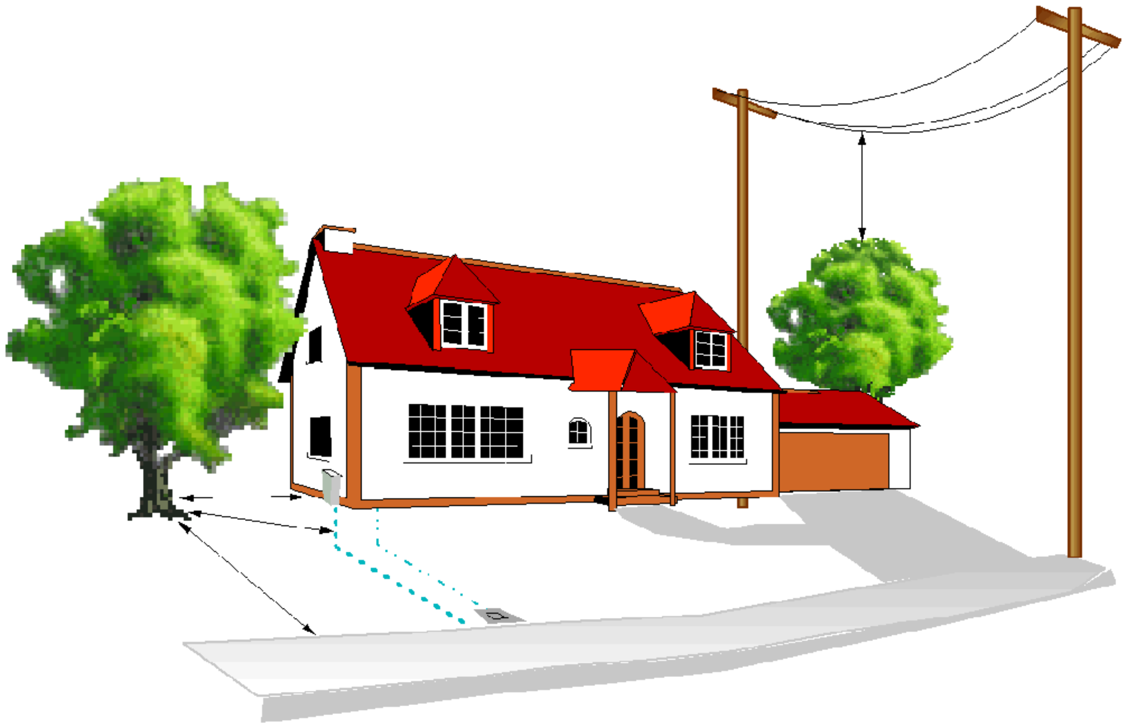

Figure 6-1. The diagram above shows some important clearances to consider when placing trees in the landscape. At maturity, trees should have adequate clearances from structures, above- and below-ground utilities, and the City Public Utilities Easement along the street.

Rooting space

Adequate space must be allowed for tree roots. Infrastructure damage caused by tree roots is a costly problem for many California cities (Costello and Jones, 2003). Most tree roots are limited to the upper 2 to 3 feet of the soil profile, and many of the most important roots occur within a foot of the soil surface. Roots also typically radiate out well beyond the edge of the canopy, often to a distance 2 to 3 times that of the canopy spread. The potential spread of the root systems should be considered when placing trees in landscapes and when preparing soil at the planting site.

Choosing trees that will not outgrow the planting space available is an important step in preventing damage to sidewalks and curbs. Most trees eventually produce buttress roots and trunk flares that serve to anchor and support the tree. Larger trees will tend to have larger buttress roots, but all sizeable trees will produce some large-diameter buttress roots. .

In a study on hardscape damage in Southern California, Lesser (2001) found that more hardscape damage was associated with medium-statured trees (30-60 feet tall), than with large trees (>60 feet tall). His study was strictly correlative, and did not control for distance from hardscape. One possible reason for the greater damage rates associated with medium-statured trees is that they tend to be planted in spaces that are too small for the buttress roots that eventually develop. For example, some City tree lists indicate that European hackberry can be used in planters as small as 48 inches wide. However, in the Bay Area, European hackberry has an average diameter at ground level of 38.6 inches (Costello and Jones 2003). A 48 inch planter would be inadequate for a tree with a diameter at ground level of 38.6 inches.

Trees with substantial trunk flares or buttress roots can have an effective diameter at ground level 2 to 3.5 times that of the stem diameter measured just above the root flare. As a general rule, the minimum unobstructed space needed for root flare expansion around the base of most tree species is 3 to 4 times the anticipated mature stem diameter above the root flare. Hence, for a tree with a diameter above the root flare of 2 feet (which would be less than 2 feet DBH), at least 6 to 8 feet of space should be allowed to avoid conflicts between roots and the surrounding paving. For species with especially wide bases, the minimum space may need to be increased further. By collecting local data on trunk diameter at ground level for mature trees of various species, the City can develop more precise guidelines that reflect local soil and tree growth conditions.

Some trees are more likely to develop surface roots than others (Costello and Jones 2003). Trees that have a tendency to produce surface roots that can damage hardscape are noted in the species list below. Trees that tend to produce extensive surface roots generally should not be used in narrow planting spaces or in lawns, especially on soils that tend to encourage surface rooting.

Tree placement for energy conservation

Appropriately-placed trees can greatly reduce energy costs associated with cooling and heating (see also Section 1). Walls shaded by trees are generally 15° F cooler than unshaded walls. Shading windows with trees prevents heat buildup inside more effectively than curtains or blinds. Also, trees can reduce wind speed near a building, reducing the rate of heat exchange between the inside of the building and the outside, which can lower both winter and summer energy costs. Some factors to consider when placing trees near buildings to maximize energy savings are as follows:

- Walls facing east and west receive maximum exposure to sun during the middle of summer and are the most important parts of the building to shade. At midday in midsummer, the sun is very nearly directly overhead, so it is difficult to effectively shade south-facing walls at that time of the year (Figure 6-2).
- Deciduous trees should generally be used to provide summer shade for buildings. When these trees lose their leaves in fall, they allow sunlight to reach and warm the building and reduce heating costs in the winter. Both evergreen trees and deciduous trees that hold their leaves well into the winter, such as pin oak, can interfere with winter solar heat gain. To provide maximum energy savings, evergreen trees should be planted north of buildings to avoid winter shading while still providing a screen against cold north winds.
- Shading air conditioners in the summer will improve their efficiency and save energy.

By using trees to shade sidewalks, patios, and pavement to reduce the amount of heat that is reflected from and stored in these surfaces, the entire vicinity of the building can be cooled in the summer.

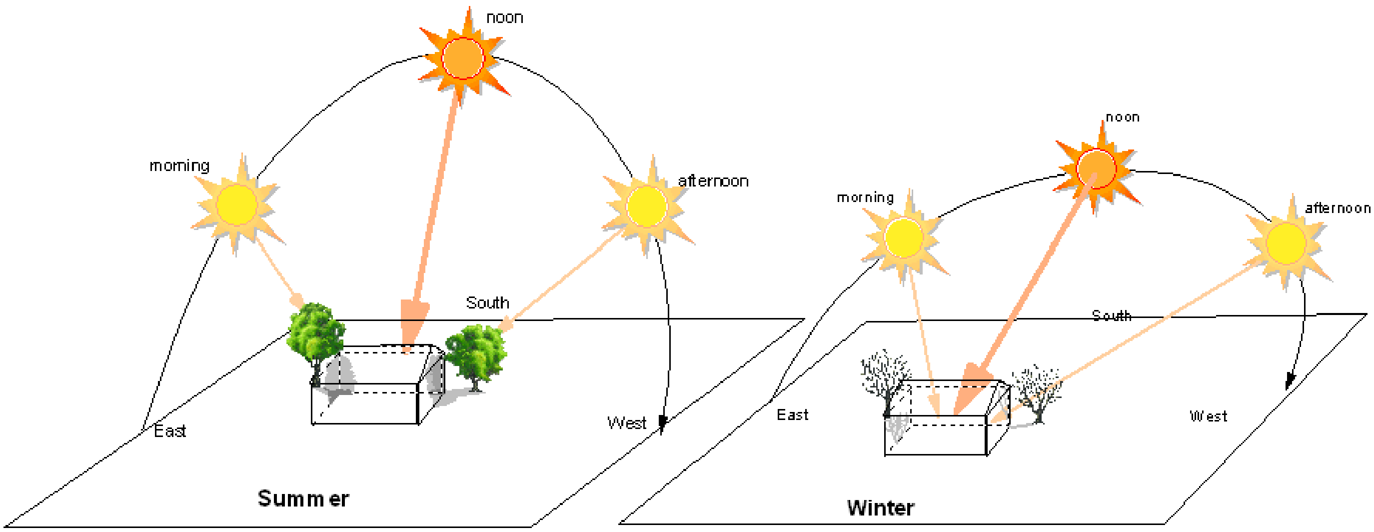

Figure 6-2. Tree placement for energy conservation is influenced by the fact that solar angles are greater in the summer than in the winter. Because of the high solar angle in summer (left), it is difficult to provide direct shading near noon. Trees planted to the east and west provide shade when the sun is at lower angles in the morning and afternoon. In winter, deciduous trees lose their leaves, allowing greater solar heating. Note that winter midday sun is unobstructed to provide maximum solar heating.

Spacing between trees

Trees compete with each other for light and soil moisture, and such competition can reduce growth or lead to branch dieback. Normally, trees should be planted at a density and spacing that will allow each tree to reach its mature size without more than about 10-20% overlap of adjacent tree canopies. For example, trees with a mature spread of 30 feet should be spaced no closer than 24 to 27 feet apart. Somewhat higher level of overlap may be used when adjacent trees are only present on one or two sides, such as for trees planted in a line. Use the minimum or no overlap between adjacent canopies if trees are in a grid or will be surrounded by other trees on more than 2 sides. Also, in dry sites with little or no irrigation, trees should be spaced more widely (at or above mature canopy width) to reduce competition for soil moisture.

In some situations, “temporary” trees, extra trees spaced more closely than recommended for mature trees, may be planted to provide early cover or screening. As tree canopies expand to the point that they begin to overlap, the temporary trees should be thinned out to allow adequate space for the permanent trees, which should be at the recommended spacing.

6.2. Species selection

In order to selecting an appropriate tree for a given site, a number of questions should be answered.

1. What are the intended functions of the tree at the site?

Trees can serve multiple functions in the landscape. As discussed above, properly selected and located trees can be used to reduce energy costs in both winter and summer. Appropriately placed trees can also provide visual screening and privacy, but may also block desirable views. The height and density of the canopy and leaf retention (evergreen or deciduous) need to be considered when selecting trees to screen views. Trees can also be used to provide visual accents and interest, due to flowers, overall form, and/or foliage shape and color, especially fall color. If the tree is being selected with several objectives in mind, it may be necessary to prioritize the functions. For example, many species grown for showy flowers are not large enough to provide significant shade for energy conservation.

2. How much space (above and below ground) is available for the tree?

As noted in the discussion of tree placement (Section 6.1) above, urban sites may present a number of constraints that limit the size of trees that can be planted. The available growing space needs to be large enough to accommodate the mature size of the tree. Tree maintenance is easier and less expensive for trees that fit the available space compared to trees that grow too large for the available space.

3. Can the tree perform well in the soil type and soil conditions at the site?

As discussed under Soil Management (Section 6.4) below, the native soils in Rocklin vary from deep to shallow, well-drained to waterlogged, and sandy to clayey. Furthermore, soil conditions can be altered substantially by compaction and grading, including the construction of berms. These alterations can further limit the amount of water stored in the soil, drainage, and other factors that influence root growth. Trees will not perform well if they do not tolerate soil conditions at the site.

4. How much water will the tree require or tolerate?

With the exception of tree species native to Rocklin that are growing in unaltered sites, relatively few trees can survive and perform well in Rocklin unless they are irrigated or are able to tap into a shallow water table. The amount of irrigation necessary to maintain a tree in good condition becomes especially problematic in situations where the irrigated area is limited, as in a parking lot planter. In small planting beds, the amount of irrigation water that can be delivered to the tree's root zone can be quite limited, and only drought tolerant species may be viable in such sites.

Too much water can also limit tree survival. Areas with high water tables and turf areas that receive frequent summer irrigation may be too wet for some species, especially Rocklin's native blue oak.

5. How much maintenance will the tree require?

The amount of pruning needed to maintain trees can vary widely. Slower-growing trees typically require very little pruning, but may still need pruning when young to establish good branch structure. Trees that have high levels of branch dieback or are prone to breakage in storms are likely to require more frequent pruning.

In addition, virtually all trees will drop leaves, twigs, seeds, or other materials at some point during the year. Aphids, scale and other insects that suck tree sap can drip sticky exudates that are deposited beneath affected trees. Trees that are subject to aphid problems or that shed a lot of debris should be avoided in areas where the materials falling from the tree will cause major maintenance problems.

6. Can the tree perform well in the climate and microclimate conditions at the site?

Rocklin's climate is classified as USDA Plant Hardiness Zone 9. The division between subzone 9A and the slightly warmer subzone 9B occurs in the Rocklin area. The Sunset Western Garden Book's climate zone designation for Rocklin is also zone 9. Rocklin's climate is characterized by very hot summer temperatures that can exceed 100°F from late spring through early fall (Figure 6-3). Winter temperatures can dip as low as about 15°F, although winter lows are commonly above freezing. Nonetheless, because tree survival can be affected by temperature extremes, trees planted in Rocklin should be capable of surviving low temperatures to about 15° to 20°F. Species such as Canary Island pine (*Pinus canariensis*), whose needles freeze at about 20°F, will make it though many winters unscathed but will sustain significant levels of unsightly damage following extreme low temperature episodes.

Local microclimates can differ from Rocklin's overall climate, especially with respect to temperature extremes. Trees surrounded by pavement or along south-facing walls of large structures may be exposed to higher peak summer temperature maxima due to heat reflected or re-radiated from these surfaces. Low areas are much more likely to frost or freeze than are areas on slopes. Due to these differences, trees that tolerate the temperature regime in some parts of Rocklin may suffer damage from temperature extremes in other parts of town.

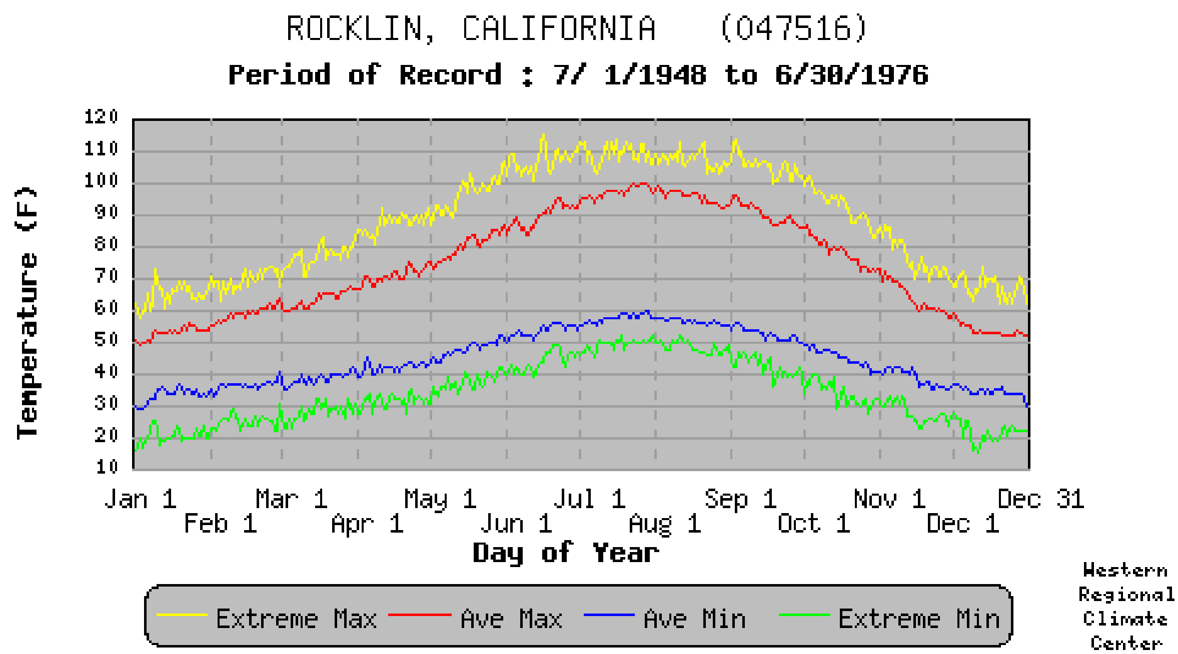

Figure 6-3. Daily average and extreme maximum and minimum temperatures for Rocklin (from Western Regional Climate Center http://www.wrcc.dri.edu/summary/climsmnca.html).

7. Is the tree already overrepresented in Rocklin's urban forest or in the local area?

One basic concept of urban forestry is that trees in cities are part of a population of trees. One consequence of this is that diseases or pests that attack a given tree species are more likely to build up and spread if the species is common. This phenomenon was responsible for extensive losses of mature elm street trees due to Dutch elm disease in many US cities in the middle part of the 20th century.

Lack of diversity can be a greater problem in urban forests than in natural forests because the amount of genetic diversity within species is commonly low in urban forests. Trees that are named varieties (e.g., Capital pear, *Pyrus calleryana* var. 'Capital') are clonally propagated selections, i.e., all trees of the variety are derived from cuttings that originated from a single tree. Hence, all individuals of such named varieties are genetically identical. Most native forest trees develop from seed, and populations derived from seed can have high amounts of genetic diversity, reducing the chance that all trees will be uniformly susceptible to pest and disease problems.

Individual tree species selections play a role in developing and maintaining reasonable levels of diversity within the urban forest. Nonetheless, one should not attempt to increase species diversity by replacing well-adapted species with poorly-adapted ones. Genetic diversity goals should be used to help decide between species or the overall ratio of species used when there are several well-adapted species that could be planted at a site.

8. Is information on the long-term performance of the tree in the Rocklin area available?

Many tree species used in the urban forest have the potential to live well over 100 years. However, even a potentially long-lived species, such as a coast redwood, may have a short lifespan when it is planted in an unfavorable situation.

Problems associated with poor adaptation may not become obvious until a tree is 10 to 20 years old or older. By that time, a poorly adapted tree may have grown large enough that site constraints have become chronically limiting. For example, the limiting effect of low soil water-holding capacity can be offset by frequent irrigation. However, as a tree grows and its water needs increase, a tree that has high water needs may reach a point where no realistic irrigation schedule can supply the amount of water needed during peak demand period. As a result, the tree may become water-stressed and begin to die back. Opportunistic pests and diseases that attack stressed trees may then colonize the tree and further degrade its condition. In contrast, a well-adapted tree will typically be adequately established after 10 to 20 years and will begin providing higher levels of shade and other benefits.

Information on tree characteristics, including their tolerances to climate, soils, and water regimes, is available from a number of sources (see Section 6.8 below). This information can be used to rule out species that are unlikely to perform well and identify species that may do well in an area. However, long-term (i.e., at least 20 to 30 years) local experience with a species provides good empirical data on how a tree actually performs under local conditions. Such information is normally lacking for new species and cultivars. Some species such as Modesto ash, and more recently Raywood ash, were widely planted when they first became available, but have fallen out of favor after they have developed chronic problems over the long-term.

While it can be interesting and useful to experiment with species that do not have a long history of local use, one must realize that such species are experiments and may not work out over the long term. Hence, these experimental species should be planted on a relatively limited basis until local long-term results are available. Species that have a good record of long term success locally are a safer choice for sites where successful tree establishment is critical. However, even for trees that have good overall track records in the local area, it is important to assess site characteristics to ensure that selected species are a good match of the site.

Other factors

Answers to the preceding questions will narrow down the number of potential species that may be suitable for the site. At that point, one can weigh other advantages (e.g., fall color, flowers, fast growth) and disadvantages (e.g., litter, pests, allergenic pollen) of various candidate trees. Once one or more species are selected, availability of the planting material from local nurseries or other available sources may further limit which species can be selected.

6.2.1. Developing a list of tree species potentially suitable for landscape uses in Rocklin

It should be clear from the preceding discussion that there is no single “perfect tree” for a given site. Similarly, it is not possible to develop a list of species that will be optimal for all planting situations throughout Rocklin. To develop the species list in Table 6-1, Phytosphere integrated information from a wide variety of sources, including:

- the SelecTree database, hosted at the Urban Forest Ecosystem Institute (UFEI) at Cal Poly San Luis Obispo (http://selectree.calpoly.edu/);
- USDA tree species fact sheets, available from the Institute of Food and Agricultural Sciences (IFAS) at the University of Florida (http://hort.ifas.ufl.edu/trees/);
- the Sunset Western Garden Book (Brenzel 2001);
- results of a statewide survey of California City tree programs conducted in 1988 (Bernhardt and Swiecki 1989)
- recommended species lists from a number of cities in the area and throughout California;
- results of a survey (Appendix 7.5) Phytosphere distributed to City of Rocklin Public Works and Parks Division of the Department of Community Services and Facilities staff and members of the Sacramento Valley Regional Urban Forest Council, which includes City arborists and other tree program staff from public and private organizations in the Sacramento Valley.

These sources sometimes do not completely agree with respect to the merits or disadvantages of various species. Phytosphere interpreted and integrated the information from these sources in the light of their own experience and observations of trees in Rocklin and elsewhere in the region.

Included and excluded species

Because planting situations vary widely, often over short distances, it is not possible to produce a list of trees that can be recommended without reservations for every site. Table 6-1 includes many tree species that have a high probability of performing well in many parts of Rocklin over the long term. However, some species on the list can only be recommended on an experimental basis because long term data from the local area are lacking. The “notes” column in Table 6-1 indicates which trees are considered to be experimental for use in Rocklin.

Table 6-1 also includes some species that may have limited life spans or uses that are limited to specific situations. For example, coast redwood is a popular species in Rocklin, due to its ability to tolerate lawn irrigation, its rapid growth, and its attractive appearance when young. However, Phytosphere generally advises against the use of this species in Rocklin due to its high water requirement and poor prospects over the long-term. Redwoods are entirely dependent on high amounts of irrigation for survival in the Rocklin area, and can suffer substantial dieback when water demands are not met for even a short episode. If drought conditions were to result in summer irrigation restrictions, substantial dieback could be expected to occur in this species throughout Rocklin. Even without irrigation restrictions, most Rocklin soils have low water holding capacities (see Section 6.4) and coast redwood trees will eventually outgrow the available water supply in many sites, leading to chronic water stress. Chronically-stressed coast redwoods are susceptible to a canker disease that causes extensive canopy dieback.

The species list, like all such lists, should be considered a starting point for identifying species that may be appropriate to use in specific situations, rather than interpreted as a definitive list of recommended species. Some species currently on the list may eventually develop unanticipated problems due to new pests or diseases or other factors which could lead to their eventual exclusion from the list. In addition, other species not currently included on this list may prove to be suitable for use in Rocklin. This list should be reviewed at least every two years to add or remove species or make additional notes on assets or liabilities based on local experience.

The list also excludes certain species for a variety of technical reasons. Some of the more prominent excluded species are presented in Table 6-2 along with the reasons they have been excluded. A few of these species (e.g., some ash species/varieties) may be usable in a few specific situations, whereas others (e.g., tree of heaven) should be avoided in all cases. Also excluded are species that are considered to be invasive in native ecosystems, especially riparian ecosystems.

In general, the list emphasizes species that grow large enough to function as trees in the urban environment. Most species that are essentially large shrubs that can be grown as very small trees have not been included in the list. While these plants have a definite role in urban landscapes, they provide few of the benefits associated with trees.

Various trees used primarily for fruit and nut production can be grown successfully in Rocklin, and some of these trees are large enough to function as shade trees as well. These species are not specifically included in Table 6-1. The use of such trees is typically limited to backyard planting situations where falling fruit will not pose a nuisance.

Many trees that are widely reported to produce abundant and troublesome surface roots have been excluded from the list. However, if the soil depth is shallow, due to either limited soil depth or compaction (which is so often the case in urban environments), almost all trees will develop shallow roots, and so will require greater planting space. London plane is an example of a tree which exhibits substantial root flare development in shallow soils, but not in deep soils. In addition, some surface roots can be tolerated in large planting areas away from hardscape, as might occur in some yards and parks.

The list deemphasizes the use of oak species that are not native to Rocklin partly due to questions about long-term adaptation. In addition, the widespread use of non-native species in the white oak and black oak subgroups that may have the potential to hybridize with local native species may be a cause for concern. Such hybrids may be more poorly adapted to local conditions and could have negative consequences for the sustainability of locally native oak populations. In particular, coast live oak, which is native to California but not to the Rocklin area, hybridizes readily with the local interior live oak. Since both species are similar in form and appearance, Phytosphere recommends that locally-native interior live oak should always be planted in preference to coast live oak in Rocklin.

6.2.2. Information in the list of tree species potentially suitable for landscape uses in Rocklin

Water requirements

Table 6-1 indicates the relative amount of water trees are likely to need after they have become established. Ability to withstand drought does not develop for drought tolerant species, until plants have become well established in the landscape. Values are from Costello et al (2000). The estimates for water needs in the publication are consensus estimates of expert opinion for the Central Valley. Categories for water requirements are as shown below.

H=high water need (70 to 90% of ETo)

M= moderate water need (40 to 60% of ETo)

L=low water need (10 to 30% of ETo)
VL=very low water need (less than 10% of ETo)

Reference evapotranspiration (ETo) corresponds to the amount of water needed to grow a 4 to 7 inch tall field of cool season grass in full sun in the Rocklin area. Table 6-4 in Section 6.6 below provides estimates of the monthly water requirements for trees in the high, medium, and low water use categories. Trees in the low and very low water need categories are considered drought tolerant. Established trees in the very low water use category typically do not require irrigation.

Tree height and spread

The tree height categories used in Table 6-1 are:
S (small) = less than 20 feet tall
M (medium) = 20-40 feet tall
L (large) more than 40 feet tall.

Maximum reported tree canopy spread is given in feet. The median spread of the trees in the table is 30 feet. Trees with a canopy spread of 35 feet or more are considered to have a wide canopy spread.

Size estimates were based on estimates for trees growing in urban environments. Although some trees will grow quite large in their native forests, mature tree heights are commonly shorter in urban situations where restricted rooting volume and suboptimal climate conditions limit tree growth. Sizes given are expected mature heights under Rocklin conditions, which may be lower than reported in some sources. Depending on site conditions, trees may not attain the maximum sizes listed in the table.

Trees in the small height class can normally be planted under power lines. Some of the shorter trees listed under the medium height class may also be suitable under or near power lines. As noted earlier, there should be at least 10 feet of clearance between high voltage power lines and tree branches when the tree is at its mature size.

Potential use situations

Table 6-1 indicates whether species may be suitable for various planting situations. Phytosphere considered multiple factors, including tree size, drought tolerance, propensity for surface rooting, and litter production before assigning trees to various potential uses. These ratings are not absolute, but are general guidelines. A question mark (?) is used to denote uncertain or very limited use situations.

Small planters: Species may be suitable for use in relatively small planters, 6 to 8 feet on a side, in street or parking lot plantings. Planters less than about 6 feet wide are not suitable for most species, especially given Rocklin’s soil types.

Parking lots/street planting beds: Species may be suitable for use in parking lot or streetscape planting beds. These are typically harsh sites with reflected heat, minimum soil volumes, and often low water availability. Trees with high potential for surface rooting and consequent damage to hardscape are not suitable for these sites.

Residential yards: Residential yard plantings are quite variable in their characteristics. In general, recommendations in this category are based on the assumptions that residential yards will have moderate amounts of space, only moderate rootzone limitations, and can receive regular irrigation. Tree characteristics should be reviewed carefully to determine whether a given tree is appropriate for a specific yard site.

Parks: Park environments are also variable, but recommendations in this category are based on the assumptions that above-ground growing space and rootable soil volume are generally not limited and that irrigation can be applied regularly. Not all species listed for parks will tolerate lawn irrigation regimes.

Assets, liabilities, and notes

Most trees have both assets and liabilities, i.e., characteristics that may be positive or negative in a specific use. Notes on assets and liabilities of trees in Table 6-1 are compiled from various sources, including local information where available. These characteristics should be considered carefully before selecting a species for use in a given application.

Plants noted as tolerant of waterlogged soils are not likely to be tolerant as young, newly transplanted trees. It takes several years for a plant to develop a root system that can tolerate flooded conditions.

All trees shed various plant parts (leaves, twigs, fruits, bark, flowers) at varying times of the year. Some trees may also drip sticky sap or honeydew, especially when infested by certain insects such as aphids. Litter fall and sap dripping are only noted for species that produce notably high amounts, produce litter or sap over an extended period, or where dropped materials are especially problematic (e.g., large fruits or seeds). In general, tree-related debris poses more problems in areas where it falls on sidewalks or pavement. Individual trees may vary in the amount of seed or fruit drop. Also, amounts produced can vary from year to year. For instance, acorn production by oaks can range from nothing to heavy crops between years and among different trees.

Biogenic VOC emissions

Ground-level ozone is a colorless and highly irritating gas that forms just above the earth's surface. Ozone not only affects human health, it can damage vegetation and decrease the productivity of some crops. It is produced by sunlight in still air when nitrogen oxides (NOx) and volatile organic compounds (VOC) are present.

NOx and VOC can come from natural sources as well as from human activities. About 95% of NOx are produced by burning fossil fuels, such coal, gas and oil. VOC are carbon-containing gases and vapors such as gasoline fumes and solvents (excluding carbon dioxide, carbon monoxide, methane, and chlorofluorocarbons). The main human sources of VOCs are gasoline combustion and the evaporation of liquid fuels and solvents.

Gaseous emissions from plants are a natural or biogenic source of VOC (BVOC). Currently it is believed that the most reactive BVOC released by plants is isoprene, which is very reactive in the atmosphere. Plants vary in the amount of isoprene they release. Isoprene is primarily emitted by broadleaf species, and a few of the highest emitters include poplar, aspen, and oak. There is currently a great deal of research into the contribution of BVOCs to regional air pollution levels. Table 6-1 includes information on BVOC emission by various trees taken primarily from Winer et al (2001). Emissions levels are assigned as high (H), medium (M), or low (L) and are given for both leaves in light and in the dark. The actual levels of BVOC emissions that were measured varied with the type of instrument used. In general, emissions from trees in the high group are at least 4 to 5 times higher than those in the low group.

Because plants do not produce NOx, the contribution that plant BVOCs make to the formation of ground level ozone is almost entirely due to NOx emissions from human activities. In addition, trees and other plants absorb pollutants including ozone, nitrogen dioxide (NO_2), and fine particulates, thereby reducing ground level pollution. Given the positive impacts of trees on air quality, the current limited state of knowledge about BVOCs, and the many factors that need to be considered to pick an appropriate tree, Phytosphere does not recommend that reported BVOC emissions be used as a primary criterion for species selection. After all other factors have been considered, reported BVOC might be used, if necessary, to help decide between equally well-adapted trees. Native oaks, which constitute the majority of Rocklin's native tree cover, should not be shunned on the basis of relatively high BVOC emissions because of their adaptation to the Rocklin environment and their importance in the native ecosystem. If reducing BVOC emissions is a concern, it would make sense to minimize the use of high-BVOC non-native oaks in the urban forest in cases where other suitable lower-emitting species could be used.

Table 6-1. A selection of tree species potentially suitable for landscape uses in Rocklin. Explanations of abbreviations are given in Section 6.2.2

Scientific name	Common name	Water needs	Max height	Max spread (feet)	Small planters	Parking lots / streets	Yards	Parks	Assets	Liabilities	Notes	BVOC emissions light/dark
Acer burgeranum	Trident maple	M	M	20	yes	yes	yes	yes	showy yellow spring flowers, fall color, bark		Good maple for smaller area. Highly regarded. Naturally has several stems, but can be pruned to a single stem.	L/L
Acer campestre	hedge maple	M	M	30	yes	yes	yes	yes	yellow fall color		Slow growing. Naturally has several stems, but can be pruned to a single stem.	L/L
Acer palmatum	Japanese maple	M	S	20	no	no	yes	yes	spring and fall color, winter interest	leaf scorch in hot, dry winds, sensitive to salt in soil	Slow growing. Most named varieties will grow no taller than 15 ft and many grow no taller than 10 ft. Sangu Kaku ('Senkak') can grow to 20 ft. Resistant to oak root fungus. Best in filtered shade, avoid west-and south facing exposures, prefers evenly moist, well drained soil.	L/L
Acer rubrum	red maple 'October Glory'	H	M	30	no	no	yes	yes	shade, fall color, winter interest	root damage	Fast growing. Use only nongrafted varieties. Water demanding. Develops surface roots. Watch for girdling roots. Can form narrow branch angles susceptible to storm damage, requires attention to pruning. Tolerant of waterlogged soil.	L/L
Aesculus californica	California buckeye	VL	S	30	no	no	some	some	Rocklin native, drought tolerant, early leaf out, spring flowers	large seeds, drought deciduous	Attractive in spring, but defoliates in summer; best used in natural areas - large seeds (buckeyes) a problem in lawns, sidewalks. Can be grown directly from local seed.	M/H
Arbutus unedo	strawberry tree	L	S	20	yes	yes	yes	yes	Evergreen shade, attractive flowers, fruit, and bark add visual interest	fruit	Slow growing. Fruit messy, hummingbirds love flowers, can take xeriscape to lawn water.	L/L
Calocedrus decurrens	incense cedar	M	L	20	no	no	some	some	bright green evergreen		Evergreen. Needs large space. Needs irrigation in Rocklin, marginal in very hot sites. Needs good drainage, not for heavily irrigated turf areas.	M/L
Cedrus deodara	deodar cedar	M	L	40	no	?	yes	yes	dark green evergreen		Evergreen. Needs large space. Generally performs well if it has adequate room.	L/L

Table 6-1. continued (see Section 6.2.2 for explanations of columns and abbreviations)

Scientific name	Common name	Water needs	Max height	Max spread (feet)	Small planters	Parking lots / streets	Yards	Parks	Assets	Liabilities	Notes	BVOC emissions light/dark
Celtis australis, C. occidentalis C. sinensis	hackberry: European, Common, Chinese	L common M others	L	35	no	some	yes	yes	shade; European has least problems of the 3 species	Aphids on common and Chinese. Surface roots occasional. Common hackberry is reported to be highly invasive.	Occasional summer water for Chinese or European. Common more drought tolerant. Asian woolly hackberry aphid attacks most *Celtis* species, results in sticky sap dripping from trees, but has been less severe on European so far. A new pest in Sacramento area; biological control of this pest may be possible in the future.	L?
Cercis canadensis	eastern redbud	M	S	20	yes	yes	yes	yes	pink spring flowers, more treelike than western redbud		Drought tolerant in its native range, but requires moderate water here. Varieties *mexicana* and *texensis* are more heat/drought tolerant. Intolerant of waterlogged soils.	L/L
Cercis occidentalis	western redbud	VL	S	18	yes	yes	yes	yes	pink spring flowers, very drought tolerant		This CA native is shrub-like, but can be pruned to a multistemmed tree.	H/M
Chilopsis linearis	Desert willow	VL	S-M	25	yes(?)	yes	yes	yes	showy summer flowers	may establish from seeds	Needs pruning to establish good structure but not prone to breakage. Early growth is rapid. Needs good drainage. Try in shallow dry soils.	L/H
Chionanthus retusus	Chinese fringe tree	M	S	20	yes	yes	yes	yes	showy, white spring flowers	purple berries on female trees	Not much local experience with this tree. Fruit may attract birds, slow growing.	L/L
X Chitalpa tashkentensis	Chitalpa	M	M	30	?	?	?	?	showy summer flowers	no long term track record; some disease and growth form problems noted, useful life unknown	Consider as an experimental species. Fast growing. A hybrid of *Chilopsis linearis* and *Catalpa bignonioides*. As wide as tall, too short to prune for street clearance. Some reports of poor performance related to poor root structure and related instability. Poor in turf, heavy soils, rocky soils. Problematic to prune because numerous vigorous upright epicormic shoots are produced near all cuts. Can develop deep bark cracks. Summer leaf drop and other foliar problems have been reported in some areas.	L/M

Table 6-1. continued (see Section 6.2.2 for explanations of columns and abbreviations)

Scientific name	Common name	Water needs	Max height	Max spread (feet)	Small planters	Parking lots / streets	Yards	Parks	Assets	Liabilities	Notes	BVOC emissions light/dark
Cinnamomum camphora	Camphor tree	M	L	60	no	no	no	?	broadleaved evergreen	litter, surface roots, roots are competitive and invasive	Slow growing. Abundant black berries attract birds, stain cars. Constant rain of litter- leaves in spring, flowers, fruit and twigs. Surface roots spread widely compared to diameter of tree, average of 7 feet at ground level for 20 inch DBH. Aggressive roots problematic if planted near gardens or poorly-sealed sewer pipes. Susceptible to *Verticillium*. Might be useful in some park situations. Invasive in FL, HI.	L/L
Cupressus arizonica var. arizonica or C. glabra	Arizona cypress	VL	M	25	?	yes	yes	yes	evergreen	flammable	Evergreen, use on well drained soils, on clay soil susceptible to windthrow. Fast growing. Branches susceptible to wind breakage. May be appropriate as screen or accent in some places.	L?
Fraxinus americanum	white ash cultivars 'Autumn Purple', 'Chicago Regal'	M	M	35	no	no	?	?	shade	surface roots, needs pruning to develop strong structure	Consider as an experimental species. Not much experience with this tree locally. Fast growing. Supposedly widely adaptable to many different soil situations. Use non-grafted stock.	L/L
Fraxinus pennsylvanica	green ash cultivars 'Patmore', 'Centerpoint' 'Leprechaun'	M	M	35	no	no	?	?	shade	surface roots, needs pruning to develop strong structure	Consider as an experimental species. Not much experience with this tree locally. Fast growing. 'Leprechaun' is a dwarf, reported to grow 15-20 ft tall. Tolerant of flooded or waterlogged soils, more drought tolerant than white ash.	L/L
Ginkgo biloba	ginkgo	M	L	30	yes	yes	yes	yes	fall color, tolerant of harsh urban conditions	messy, foul-smelling fruit in female trees only	Use only male fruitless varieties. Slow growing until established; good drainage; needs occasional deep watering, resistant to breakage.	L/L

Table 6-1. continued (see Section 6.2.2 for explanations of columns and abbreviations)

Scientific name	Common name	Water needs	Max height	Max spread (feet)	Small planters	Parking lots / streets	Yards	Parks	Assets	Liabilities	Notes	BVOC emissions light/dark
Koelreuteria paniculata	goldenrain tree	M	M	30	?	some	yes	yes	Showy yellow flower clusters early summer, ornamental seed pods	self seeds, red-shouldered bug populations	Medium fast growth with strong wood, gawky in youth. Seed pods attractive in summer, drop through fall and winter. High nuisance populations of red shouldered bugs (*Jadera haematoloma*) can develop around trees. Self-seeds readily. *K. elegans* and *K. bipinnata* are similar, with seed pods initially pink rather than green. *K. elegans* is evergreen. Both have weaker wood and are more prone to breakage than *K. paniculata*.	L/H
Lagerstroemia indica	crape myrtle	L	S	20	yes	yes	yes	yes	showy summer flowers		Use only varieties resistant to powdery mildew, which disfigures leaves. Hybrids of *L. fauriei* x *L. indica* are the most powdery mildew resistant. Benefits from occasional deep watering in summer	L?
Laurus nobilis	bay laurel, sweet bay	L	M	30	yes	yes	yes	yes	drought tolerant, dark green evergreen	may get scale insects	Evergreen, prefers good drainage, but reported to have intermediate tolerance to waterlogged soils.	H?
Liriodendron tulipifera	tulip tree	H	M	30-35	no	no	?	yes	shade, tolerates lawn water	high water use, sensitive to herbicide damage, root disturbance, surface roots, aphids	Not a good match for most of Rocklin. Prefers deep, well drained, acid soils and plenty of moisture. Roots need lots of space. Aphids can build up in large numbers causing annoying sap drip. Will shed interior leaves if drought stressed. Good so far in some park situations.	M
Magnolia grandiflora varieties	southern magnolia	M	M	40 or less	no	?	yes	yes	summer flowers, evergreen	root damage, litter	Broadleaved evergreen. Has wider root system than most other trees, 4 times tree canopy diameter, common cause of hardscape damage. Old leaves shed when new growth pushes. Mature tree size differs among varieties.	M
Magnolia X soulangiana (=*M.* X *soulangeana*)	saucer magnolia	M	S	35	yes	yes	yes	yes	spring flowers		Useful as accent. A multi-trunked tree. Not tolerant of dry, alkaline, or poorly-drained soil. Large pruning wounds do not close well.	M

Table 6-1. continued (see Section 6.2.2 for explanations of columns and abbreviations)

Scientific name	Common name	Water needs	Max height	Max spread (feet)	Small planters	Parking lots / streets	Yards	Parks	Assets	Liabilities	Notes	BVOC emissions light/dark
Malus floribunda	Japanese flowering crabapple	M	S	20	no	no	yes	yes	showy spring flowers	fruit, diseases	Reportedly more disease tolerant than most crabapples, fruit small, needs good drainage. Not good in hot dry sites.	L/L
Malus X	hybrid crabapple	M	S	20	no	no	yes	yes	showy spring flowers	fruit, diseases	Fruit size and disease resistance vary between cultivars. 'Robinson' and 'Prairie Fire' are reported to be disease resistant and have smaller, less messy fruit. Needs good drainage. Not good in hot dry sites.	L/L
Nyssa sylvatica	sourgum, blackgum, tupelo	M	L	35	no	?	yes	yes	shade, red fall color	small bluish berries 0.5 inch diameter in fall	Tolerant of flooding or water logged soil. Suitable for lawns. Not for shallow dry soils. Horizontal branching structure. Great fall color. Male trees don't fruit.	H/M
Olea europaea	olive	VL	S	20	no	yes	yes	yes	drought tolerance, silvery foliage	pollen, fruit, surface roots, seedlings may be invasive in riparian areas	Use fruitless varieties 'Wilsonii' or 'Swan Hill™' to reduce or eliminate fruit. Don't use normal fruiting varies where fruit will be a nuisance, e.g., pavement. Varieties with fruit can be somewhat invasive.	L/L
Pinus canariensis	canary island pine	L	L	30	no	?	yes	yes	Evergreen shade	Sensitive to extreme low temperatures	Fast growing, narrow pyramid shape when young, eventually forms a round crown. Needles killed at 20°F, tree at 10°F.	M
Pinus eldarica	mondell pine	L	M	35	no	?	yes	yes	Evergreen shade		Upright growth habit. Not much experience with this tree in our area.	M
Pinus halepensis	aleppo pine	L	L	40	?	?	?	yes	Evergreen shade		Irregular shape. Not much experience with this tree in the Rocklin area. May be too large for most yards.	M
Pinus pinea	Italian stone pine	L	L	45	no	no	no	?	Evergreen shade, drought tolerant	Structure may become hazardous	Can grow very large with a flat top and long horizontal branches. Structure can become hazardous, due to long branches and relatively weak wood. Try to grow with central leader. Best in locations with lots of space.	L/L
Pistacia chinensis	Chinese pistache	L	M	30	yes	yes	yes	yes	fall color		Female trees have abundant small red berries. Some concern from CNPS about re-seeding into wild lands, cannot take poor drainage; Verticillium wilt can be a problem.	L

Table 6-1. continued (see Section 6.2.2 for explanations of columns and abbreviations)

Scientific name	Common name	Water needs	Max height	Max spread (feet)	Small planters	Parking lots / streets	Yards	Parks	Assets	Liabilities	Notes	BVOC emissions light/dark
Platanus acerifolia	London plane	M	L	35	no	yes	yes	yes	shade	surface roots on compacted soils, fuzzy leaf hairs can irritate eyes, nose, throat if dislodged (e.g., during pruning).	Fast growing. Hardy. Can have anthracnose problems in wet springs and powdery mildew in summer. Variety 'Columbia' is resistant to both diseases, 'Yarwood' resists powdery mildew, 'Bloodgood' resists anthracnose. Roots can cause problems if too close to hardscape.	H/L
Platanus racemosa	California sycamore	M	L	50	no	no	no	yes	shade	litter	Fast growing native normally found along streams. Can have anthracnose problems in wet springs May be useful in some park situations or in restoration plantings along streams.	H/H
Prunus cerasifera varieties, including *Prunus* X *blireiana*	purple leaf plum/ flowering plum	M	S	20	yes	yes	yes	yes	spring flowers, purple or dark green foliage	short lived	Many varieties. Forms small plum-cherries. 'Krauter Vesuvius' has little fruit. Susceptible to many pests, reportedly can be short lived.	L/L
Pyrus calleryana varieties	flowering pear	M	M	20-30 depen ding on variety	?	?	?	?	showy white flowers in spring, fall color	short useful life (10-30+ years) because of limb break-age due to poor structure	Grows well over short term and widely used, but questionable long-term performance due to structural problems. Intermediate tolerance to flooded soil. 'Bradford' requires careful pruning due to branching pattern; branches tend to break in mature trees. 'Aristocrat' Is highly susceptible to fireblight, 'Redspire', and 'Capital' are,less susceptible, 'Chanticleer' is relatively resistant.	L
Quercus coccinea	scarlet oak	M	M/L	40	no	?	yes	yes	shade, fall color	Holds dead foliage in winter, acorn drop	Holds dead foliage in winter. Trunk known to flare widely at base, lifting pavement in small planting spaces.	H/M
Quercus douglasii	blue oak	VL	M	40-80	no	some	yes	yes	Rocklin native, high drought tolerance	acorn drop	Slow growing. Good for dry sites. Can be grown directly from local seed.	H/L
Quercus ilex	holly oak	L	L	35	no	?	yes	yes	Evergreen shade	surface roots, acorn drop	Intolerant of waterlogged soil. Not for turf areas.	H

Table 6-1. continued (see Section 6.2.2 for explanations of columns and abbreviations)

Scientific name	Common name	Water needs	Max height	Max spread (feet)	Small planters	Parking lots / streets	Yards	Parks	Assets	Liabilities	Notes	BVOC emissions light/dark
Quercus lobata	valley oak	L	L	35	no	yes	yes	yes	shade, Rocklin native	acorn drop	Fast growing in moist sites. Individuals vary in amount of litter they drop. Can be grown directly from local seed.	H/L
Quercus palustris	pin oak	M	M/L	35	no	?	yes	yes	shade, fall color	surface roots, holds dead foliage in winter, acorn drop	Strong central leader. Intermediate tolerance to waterlogged soil.	H/M
Quercus wislizeni	interior live oak	VL	L	35	no	yes	yes	yes	Rocklin native, evergreen shade	acorn drop	Fast growing. Not for turf areas. Can be grown directly from local seed.	H/M
Sequoia sempervirens	coast redwood	H	L	15-25	no	?	?	yes	Fast growth, evergreen shade, tolerates lawn water	High water needs, eventual top thinning and dieback	Grows well in the short term with plenty of irrigation, but in dry climates older trees eventually become water-stressed, develop highly tapered trunks, top thinning and dieback, and become unsightly. Phytosphere does not recommend for parking lots or street plantings due to poor long-term prospects. Should be considered only a short-term tree (perhaps 20 to 30 years), other species are better adapted to area.	M
Tilia cordata	little leaf linden	M	M	35	yes	yes	yes	yes	shade	aphids	Drought causes marginal leaf scorch, aphids can be problematic.	M?
Ulmus parvifolia varieties 'Emer 1' (aka 'Athena'), 'Emer2' (aka 'Allee')	Chinese elm, Lacebark elm, Evergreen elm	M	M/L	30	no	?	yes	yes	shade, attractive bark	surface roots, breakage	Fast growing, do not confuse with *U. pumila* which is sometimes sold as Chinese elm but is inferior. Highly resistant but not immune to Dutch elm disease. Roots can be invasive, cause hardscape damage. Needs training for good structure. The species has pendulous branches. 'Athena' medium size no penduluous branches. 'Allee' large, vaselike shape of the American elm.	L/L
Zelkova serrata	zelkova	M	L	35	no	no	yes	yes	shade	surface roots	Tends to naturally have poor structure, prune to a central leader with well spaced branches. Dutch elm and elm leaf beetle resistant. Although drought tolerant prefers moist, deep loam, growth likely to be poor on hot, dry sites.	L

Table 6-2. Common trees excluded from the list of potentially useful trees and reasons for exclusion.

Scientific name	Common name	Reason excluded from above list
Acer platanoides	maple, Norway, and hybrids	Notorious for causing root damage to hardscape, some of its hybrids with other maple species have also been reported to cause hardscape damage.
Ailanthus altissima	Tree of heaven	Do not use. Tremendously invasive in the foothill and riparian areas, should never be planted. Unpleasant odor.
Albizzia julibrissen	Silk tree	Invasive in riparian areas. Messy, may be short lived.
Alnus spp.	alder	Fast growing but often short lived, have surface roots, borers. White alder, *A rhombifolia,* is a native riparian tree in the Rocklin area, but gets drought stressed and attacked by borers without abundant water. *A. cordata* is more drought tolerant, may have some uses in parks where invasive roots will not be problematic
Betula spp.	Birch	High water needs, problems with borers, generally short lived, especially in hot climates. River birch (*B. nigra*), which is native to the eastern US, has been suggested as an alternative to the more widely planted European white birch (*B. pendula*), but should only be considered in perennially wet situations
Crataegus phaenopyrum	Washington Hawthorne, Washington thorn	Thorns, which can be up to 3 inches long, and pose a hazard to tree care workers and pedestrians limit the usefulness of this small species. High pruning needs. It is the most fireblight resistant hawthorne.
Cupressocyparis leylandii	Leyland cypress	Do not use. Fast growing but short lived due to normally fatal canker disease.
Eucalyptus spp.	Eucalyptus	Many species have problem roots, are prone to breakage, produce abundant litter, and have high maintenance needs. Poor choice for areas with high fire hazard due to flammability. Some are heavily damage in extreme cold weather events. Pests introduced from Australia, including eucalyptus longhorned borers and lerp psyllids are major problems for many species, and introductions of additional pests in the future seems inevitable.
Fraxinus spp.	Ash, most species	Most ash species grow very large and have high potential for root damage. Raywood ash (*F. oxycarpa* 'Raywood') has poor structure, borers, and canker disease problems have become widespread recently. Modesto ash (*F. velutina* 'Modesto') has surface roots, problems with anthracnose and mistletoe.
Gleditsia triacanthos inermis	Honeylocust	Gets midges, produces thin canopies, tends to have weak branch attachments, roots may damage hardscape. Poorly rated by many, but has been used successfully in some areas.
Grevillea robusta	Silk oak	Fast-growing, subject to breakage, roots damage hardscape, frost sensitive, high water needs in Rocklin area. Sap produces allergic skin reaction similar to poison oak. Poorly rated by many.
Gymnocladus dioica	Kentucky coffee tree	The state tree of Kentucky. This large tree is on the list of recommended trees for Sacramento and Davis, but does not have not much of a local track record. Reportedly very drought tolerant once established, but Rocklin's climate and soils may be too hot/dry for good performance. Has 5-10 inch long seed pods, which are vary hard and can be 'shot' from a lawn mower. Male cultivars without fruit may be available.
Liquidambar styraciflua	Sweetgum	Pronounced surface roots affecting both hardscape and turf, prone to breakage, several insect pests, spiny fruits. Needs a large irrigated site away from turf or curbs/sidewalks.

Table 6-2. continued

Scientific name	Common name	Reason excluded from above list
Morus alba	mulberry, Fruitless	Surface roots, high growth rate, especially when fertilized, and poor structural characteristics can result in high maintenance needs. Heavy pollen production. May have some uses in large irrigated sites away from hardscape
Pinus sabiniana	pine, foothill	Native to Rocklin, drought tolerant, and well adapted. However, large heavy cones, typically poor structure and elevated failure potential limit uses of this tree to open spaces and other low occupancy areas away from structures.
Populus nigra 'Italica'	poplar, Lombardy	Do not use. Invasive roots, short lived; subject to breakage, suckers profusely, high water use, develops *Cytospora* canker disease which causes death or extensive dieback.
Populus fremontii	cottonwood, western or Fremont	This native tree is common in riparian zones, where it has access to the unlimited water supply it requires for growth. It is suitable for restoration plantings in riparian zones, but not useful in urban settings. Cottony seeds considered a nuisance, wood is weak..
Prunus serrulata varieties	cherry, flowering	Rocklin climate is too hot for this species, leading to sunburn, borers, and gummosis. Needs good drainage, ample water, and generally cooler sites or will be short lived.
Quercus agrifolia	coast live oak	Although this tree has performed satisfactorily in the area, this coastal species forms hybrids with the closely-related local species interior live oak (*Q. wislizeni*). Because these hybrids may interfere with natural regeneration of this important locally-native oak, Phytosphere recommends that local interior live oak be used in preference to coast live oak. Coast live oak is also likely to be less well adapted to local climate than interior live oak.
Quercus englemanii	Englemann oak, mesa oak	This southern California species has the potential to form hybrids with the local species blue oak (*Q. douglasii*) and valley oak (*Q. lobata*). Because these hybrids may interfere with natural regeneration of these important locally-native oak, Phytosphere does not recommend its use locally. Adaptation of this species to the local climate is questionable.
Robinia spp.	Locust	Surface roots, root suckers, poor structure, high pruning needs, and prone to breakage. Poorly reviewed by most.
Sapium sebiferum	Chinese tallow	Invasive in riparian areas; on the California IPC invasive species list. Has already escaped into some of Rocklin's riparian areas.

6.3. Choosing nursery stock

Overall plant quality

The quality of nursery stock used in tree plantings can have major impacts on tree survival and performance as well as future maintenance needs. Unfortunately, until recently, much of the commercially available tree nursery stock commonly had defects such as headed stems with no central leader and poor branch structure. These defects can be difficult to correct after planting, and require additional early pruning. Other defects, such as large girdling roots, cannot be corrected after planting and will invariable lead to poor plant performance and tree loss.

By carefully inspecting nursery stock used in plantings and rejecting material that does not meet standards, one can avoid a variety of later maintenance problems and costs. The attached document "Guideline Specifications for Nursery Tree Quality" (Appendix 7.8) describes and illustrates characteristics of acceptable and unacceptable container nursery stock. The guidelines are also available online at http://urbantree.org/specs.asp.

Root diseases

Soil-borne root diseases, such as those caused by *Phytophthora* species, are commonly found in container nursery stock and pose an even greater problem than structural defects. Root diseases organisms may not only cause decline and/or death of the planted tree, but can infest the soil at the planting site, affecting subsequent and adjacent plantings. These soil-borne disease organisms can also be spread to other areas on tools, shoes, or vehicle tires that are contaminated with infested soil. Most soil-borne plant pathogens cannot be completely eliminated from soil once they are introduced, so planting infested nursery stock in the landscape can lead to permanent problems in the affected planting area.

Although inspecting the root systems of nursery stock can be useful for detecting severe root disease, root disease symptoms can be masked by the use of fungicides in the nursery. Fungicides suppress disease but do not eliminate pathogens from infected plants or infested soil. Once infested plants are placed into the landscape and the fungicide dissipates, the disease organisms can become active and spread into the soil at the site.

Various laboratory tests can be used to detect the presence of specific pathogens in nursery stock and requiring tests may be justified, especially for large plantings. Another method used to detect root pathogens is to require that plants not be treated with fungicides for a suitably long period (at least 60 days) before shipment from the nursery or between shipping and planting so that any diseases present are not masked. At minimum, records should be kept on the sources of planted nursery material. If problems subsequently develop that can be traced to diseased stock, the City would at least be able to determine the source of the stock and could avoid that source in the future.

6.4. Soil management

Trees are primarily selected and planted for the benefits that are associated with the part we see above ground. However, the soil environment into which a tree is planted largely determines whether the tree lives or dies. Tree plantings are most likely to succeed over the long term if trees are selected for their ability to grow in the soil present at a site. Although soil characteristics can be modified somewhat to improve their suitability for plant growth, corrective actions are most readily and successfully implemented before trees are planted.

Rocklin Soils

Across the City of Rocklin, soil types (Figure 6-4) and characteristics (Table 6-3) vary widely. Different soils vary with respect to the degree to which they limit tree growth, the types of trees that are likely to be best adapted to the soils, irrigation and drainage requirements, and soil preparation necessary prior to planting. Soil types play an important role in the performance of trees in Rocklin and elsewhere. A number of important properties of Rocklin soils are summarized in Figures 6-5 to 6-8. The soil characteristics that have the greatest influence on tree growth are discussed below.

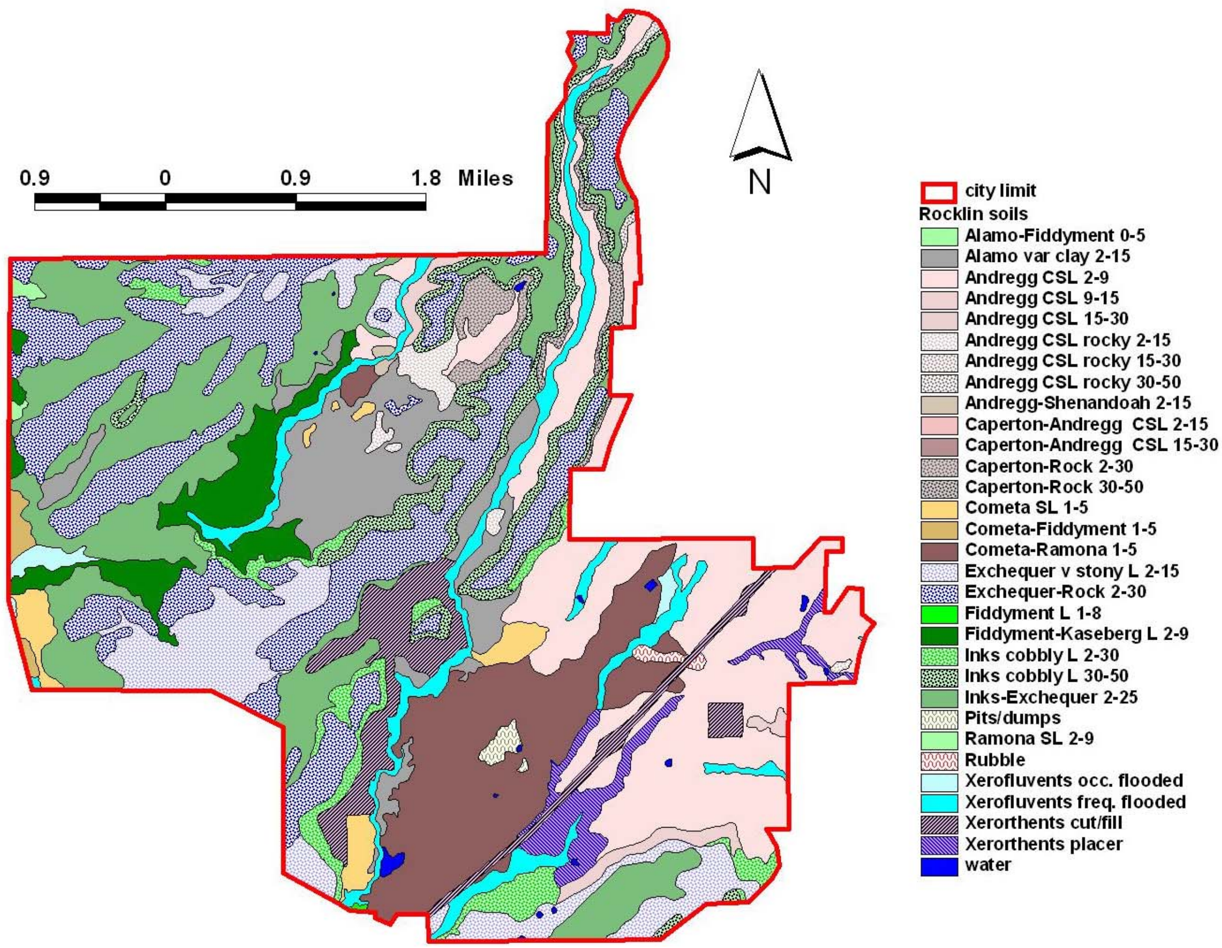

Figure 6-4. General soil map of Rocklin, based on Natural Resource Conservation Service soil survey data (Rogers 1980, SSURGO). Soil types described in detail in Table 6-3.

Table 6-3. Characteristics of Rocklin soil types, based on Rogers (1980).

Number[1]	Soil type (percent slope)[2]	Soil textures[3]	Acres[4]	Average total available water, in[5]	Minimum water table depth, ft[6]	Average (minimum) permeability, in/hr[7]	Approx. soil depth, inches[8]	Parent material[9]
104	Alamo-Fiddyment (0-5%)	clay, loam	23	2.75	0.5	1.03 (0.06)	37	sedimentary
105	Alamo variant clay (2-15%)	clay	844	7	1.75	0.13 (0.06)	36	alluvium
106	Andregg coarse sandy loam (2-9%)	coarse sandy loam	2106	3.75	>6	4 (2)	29	granite
107	Andregg coarse sandy loam (9-15%)	coarse sandy loam	142	3.75	>6	4 (2)	29	granite
109	Andregg coarse sandy loam rocky (2-15%)	coarse sandy loam	110	3.75	>6	4 (2)	29	granite
110, 111	Andregg coarse sandy loam rocky (15-30%, 30-50%)	coarse sandy loam	19	3.75	>6	4 (2)	29	granite
113	Andregg-Shenandoah (2-15%)	coarse sandy loam, sandy loam	13	4.75	1.75	3.03 (0.06)	29	granite
132	Caperton-Rock outcrop (2-30%)	gravelly coarse sandy loam	117	1.25	>6	4 (2)	18	granite
133	Caperton-Rock outcrop (30-50%)	gravelly coarse sandy loam	97	1.25	>6	4 (2)	18	granite
140	Cometa sandy loam (1-5%)	sandy loam / clay	206	5	>6	1.03 (0.06)	60	alluvium
141	Cometa-Fiddyment (1-5%)	sandy loam / clay, loam, silt loam, clay loam	54	4	>6	1.03 (0.06)	35	alluvium
142	Cometa-Ramona (1-5%)	sandy loam / clay, sandy loam, loam	1275	6.75	>6	1.03 (0.06)	60	alluvium
144	Exchequer very stony loam (2-15%)	stony loam	942	1.5	>6	1.3 (0.6)	11	andesite
145	Exchequer-Rock outcrop (2-30%)	stony loam	2117	1.5	>6	1.3 (0.6)	11	andesite
146	Fiddyment loam (1-8%)	loam, silt loam, clay loam	3	2.75	>6	1.03 (0.06)	35	sedimentary
147	Fiddyment-Kaseberg loam (2-9%)	loam, silt loam, clay loam	502	2.5	>6	1.03 (0.06)	17	sedimentary
152	Inks cobbly loam (2-30%)	cobbly loam, cobbly clay loam	375	1.75	>6	1.3 (0.6)	18	andesite
153	Inks cobbly loam (30-50%)	cobbly loam, cobbly clay loam	639	1.75	>6	1.3 (0.6)	18	andesite
154	Inks-Exchequer (2-25%)	cobbly loam, cobbly clay loam	2025	1.5	>6	1.3 (0.6)	11	andesite
173	Pits/dumps	variable	34					granite
180	Rubble land	variable	24					mining spoil
193	Xerofluvents, occ. flooded	loam, sandy loam, silt loam, clay loam	67	9	3.6		60	alluvium
194	Xerofluvents, freq. flooded	gravelly loam, gravelly sandy loam, gravelly clay loam	584	4.3	3.6		60	alluvium
196	Xerorthents, cut/fill	loam, clay loam	530	3.75	>6			various; graded soils
197	Xerorthents, placer	rocky fine sand, rocky silt	251		>6			placer mining spoil

[1] Soil type numbers in Rogers (1980).
[2] Soil name in Rogers (1980). Hyphenated names (e.g., Inks-Exchequer) are complexes of two soil types. Percent ground slopes are in parentheses.
[3] Predominant soil textures in the soil profile. Textures listed after a slash (/) are found in the subsoil only. Soil particles are smallest in clays, intermediate in silts, and coarsest in sands. Loams are mixtures of sand, silt, and clay that typically have favorable qualities for plant growth.
[4] Approximate acreage of soil type in within Rocklin City limits, based on digital soil survey data (calculated from NRCS SSURGO database).
[5] Maximum amount of water available for plant growth that is stored in the soil profile. A tree with moderate water use characteristics (e.g., London plane) would use, on average, 3.5 to 5 inches of water in July in Rocklin.
[6] Approximate depth to seasonal or permanent water table. Shallow water tables (<2 ft) can restrict root growth of trees that are not adapted to periodic flooding.
[7] Average and minimum (in parentheses) permeability rates reported for the soils. Irrigation rates in excess of the permeability rate will result in runoff. Compacted soils typically have lower permeability rates than those listed for the soil type.
[8] Minimum depth to bedrock or hardened clay subsoil.
[9] General type of material from which the soil has been derived. Andesite is a gray to black volcanic rock, sometimes referred to as "lava cap". Alluvium consists of soil materials deposited by flowing water.

Available water capacity

Available water capacity (AWC) is the total amount of water stored in the soil profile that can be used for plant growth. AWC is the amount of water held in the portion of the soil where roots can penetrate after the soil has been thoroughly wetted and allowed to drain.

Available water capacity is determined from soil texture and the depth of the rootable soil. Soils with loamy textures (certain mixtures of sand, silt, and clay) typically hold the greatest amounts of plant-available water. Sandy soils hold very little water. Soil water-holding capacity is also decreased when coarser fragments (gravel, rock) make up a high proportion of the total soil volume. As shown in Table 6-3, much of Rocklin is dominated by sandy loams, many of which are rocky, that have relatively low AWC.

For a given soil texture, AWC increases with the depth of rootable soil. Shallow soil depth limits AWC and thus can pose a significant limitation to tree growth. Some tree roots can extend into fractured bedrock beneath the soil, so the total amount of moisture available may exceed that calculated from average soil depth and texture. As shown in Figure 6-5, native soil depth is quite limited in many portions of Rocklin. Soil depth is typically altered by grading when areas are developed, which may reduce soil depth beyond that found in undisturbed native soil. As noted below, high water tables can also limit total rooting depth because most roots do not grow in permanently saturated soil. However, some trees are adapted to grow in saturated soil and utilize water in shallow water tables.

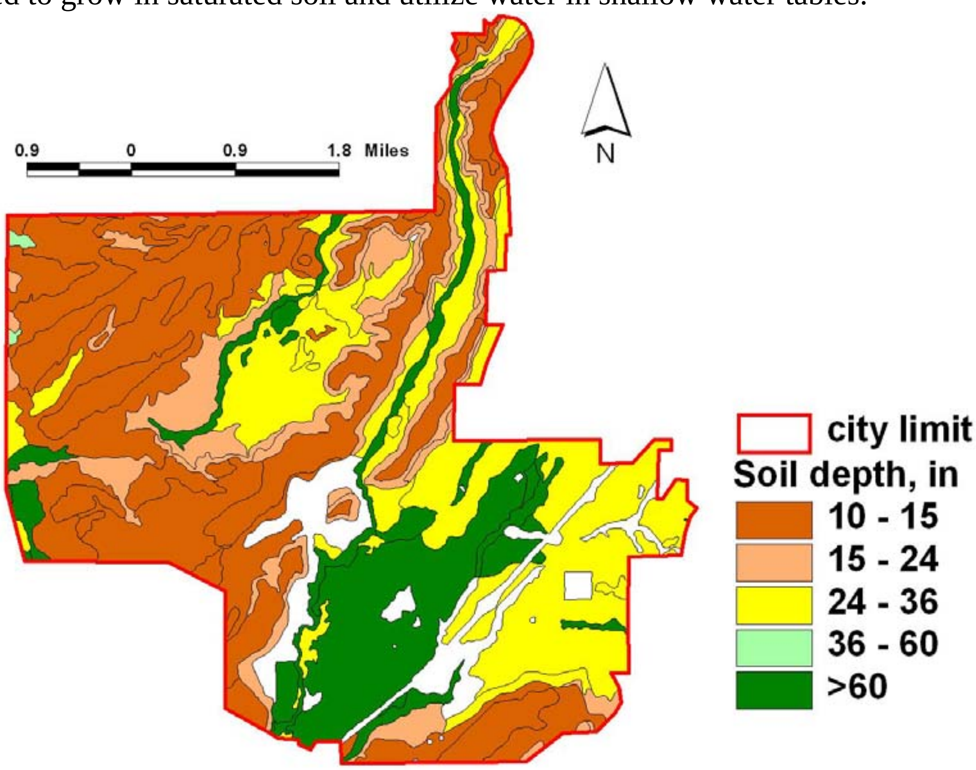

Figure 6-5. Distribution of native soil depth (in inches) in Rocklin. Deeper soils generally hold more water that can be used by trees. White denotes areas where data is lacking or highly variable.

The amount of available water that is stored in the soil influences how frequently trees need to be irrigated. Soils with high AWC can be irrigated much less frequently than those that have low AWC. Also, soils with high AWC store more moisture from rainfall, so the first irrigation of the dry season can be later in these soils. Plant water stress (due to insufficient water) develops more suddenly in soils with low AWC, such as shallow or sandy soils. Such soils are often described as "droughty". Competition for soil moisture between adjacent plants will also be more intense in soils with low AWC. This is especially the case in shallow soils, where the roots of all plants (turf, ground covers, shrubs, and trees) are all restricted to the same limited soil volume. In deeper soils, tree roots may extend deeper than the roots of at least some of the associated plants, giving them access to water that will not be tapped by other shallow-rooted species.

The distribution of AWC in Rocklin soils is illustrated in Figure 6-6. Soils with low AWC are found in much of the western and southern portions of Rocklin. High levels of AWC, which are common in the alluvial valley soils to the west, are found in only a few localized areas in Rocklin.

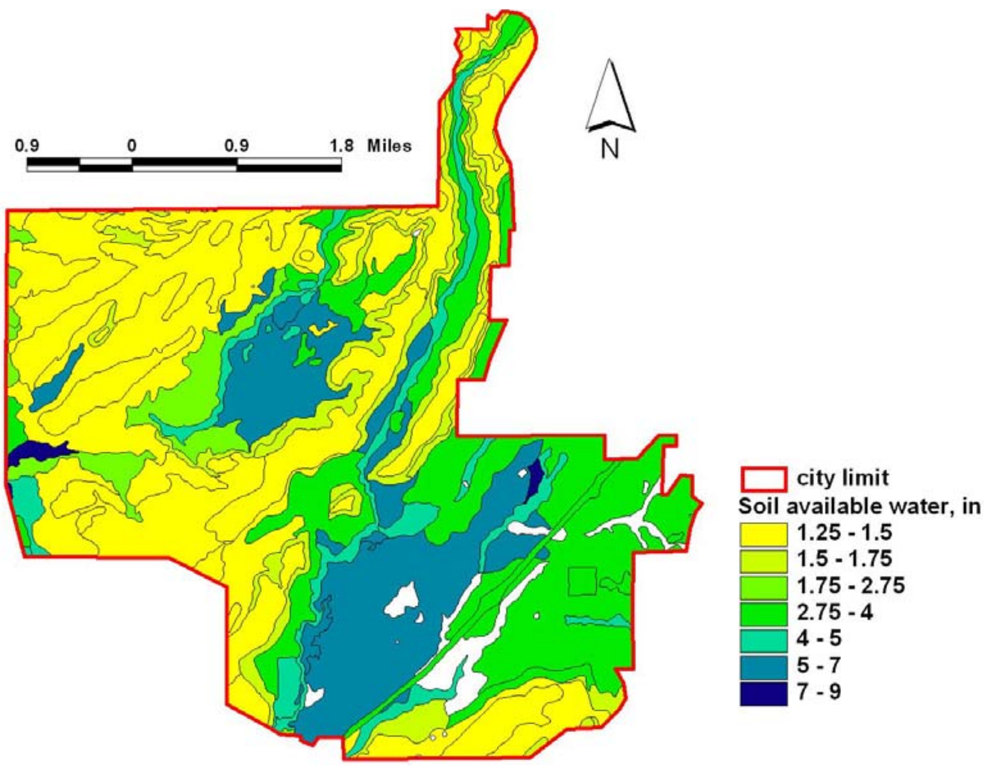

Figure 6-6. Distribution of soil available water capacities (in inches) in Rocklin. The highest available water capacities are shown in blue. Data is lacking or highly variable in white areas.

Little, if anything, can be done to increase the available water capacity of undisturbed soils. Increasing levels of soil organic matter will increase AWC somewhat. However, because organic matter decays and must be replenished on an annual basis, the degree to which soil organic matter can be elevated is limited. In general, limited AWC in undisturbed soils should be managed by selecting trees that are capable of performing well given available water constraints. Although frequent irrigation can compensate for low AWC, trees that are relatively drought tolerant are best suited to soils that do not hold much water.

In the graded soils of developed sites, the AWC of soils in planting beds can be maximized by over-excavating the bed to a depth of at least 2 to 3 feet below final grade and filling the bed with suitable native or imported topsoil. The fill soil should not be excessively compacted (see discussion on compaction below), and should be thoroughly mixed to ensure that no discrete layers of soil with differing textures are present in the soil profile. Maximizing the rootable soil within an entire planting bed is preferable to modifying only the tree planting hole. Soils that have been graded often have lower AWC than nondisturbed soil, so selection of drought tolerant species is warranted where the total soil AWC is expected to be low.

Soil drainage

Excessive amounts of water in the soil can limit the growth of trees and other plants as seriously as too little water can. Roots need oxygen to function, and soils saturated with water do not contain sufficient oxygen for most roots. Flooded situations also favor the development of some root diseases, most notably root rots caused by species of *Phytophthora*.

Limitations due to poor soil drainage are related to two factors, (1) the rate at which water infiltrates into the soil and (2), the presence of permanent or seasonal high water tables. High water tables result from local hydrology, which causes water to drain to low lying areas, and impermeable subsurface layers that prevent water from percolating deep into the ground. Hence, even soils that have high permeability (i.e., high water infiltration rates) can have high water tables if they are in low topographic positions and are underlain by relatively impermeable clay or rock. Thin layers of coarse textured material, such as coarse sand or gravel, can also interfere with percolation of water through the soil and can result in the formation of localized high water tables.

Figure 6-7 shows how native Rocklin soils vary with respect to permeability. Overall permeability rates range from slow (0.06 to 0.2 inches/hr) to moderately rapid (2 to 6 inches/hr). In Rocklin, slow rates of permeability are found mainly in clay soils of the Alamo soil series, although some soils in other soil complexes may also have low permeability rates. Permeability rates of all soils are reduced when they are compacted for building purposes, so most developed areas may have lower permeability rates than those specified in Table 6-3 and Figure 6-7.

Soils with slow permeability rates will tend to be saturated for extended periods during the rainy season, especially when they are located in low, flat or depressed areas. These soils will also tend to become saturated readily when irrigated. As a result, irrigation water will tend to either pool or run off if it is applied at too high a rate or for extended periods. Such soils require slow irrigation rates and may require many repeated irrigation cycles to allow water to penetrate to deeper soil layers without running off.

High seasonal or permanent water tables also exist in parts of Rocklin as the result of native soil conditions (Figure 6-8). The highest natural water tables are associated with the Alamo clay soils, which also have low permeability (Figure 6-7) and tend to occur in low-lying areas. In addition, localized high water tables may have been created in some developed areas through changes in topography, grading, soil compaction, and applied irrigation water.

Constructing and planting on berms or raised planters may be used to increase the volume of nonsaturated soil, but drainage and total rootable soil volume may still be limited in these sites. In sites where a high water table is associated with a shallow hardpan, it may be possible to break through the hardpan with tillage to promote deep percolation and lower the water table. However, such soil alterations should not be attempted in areas that may change the hydrology around protected vernal pools and natural watercourses.

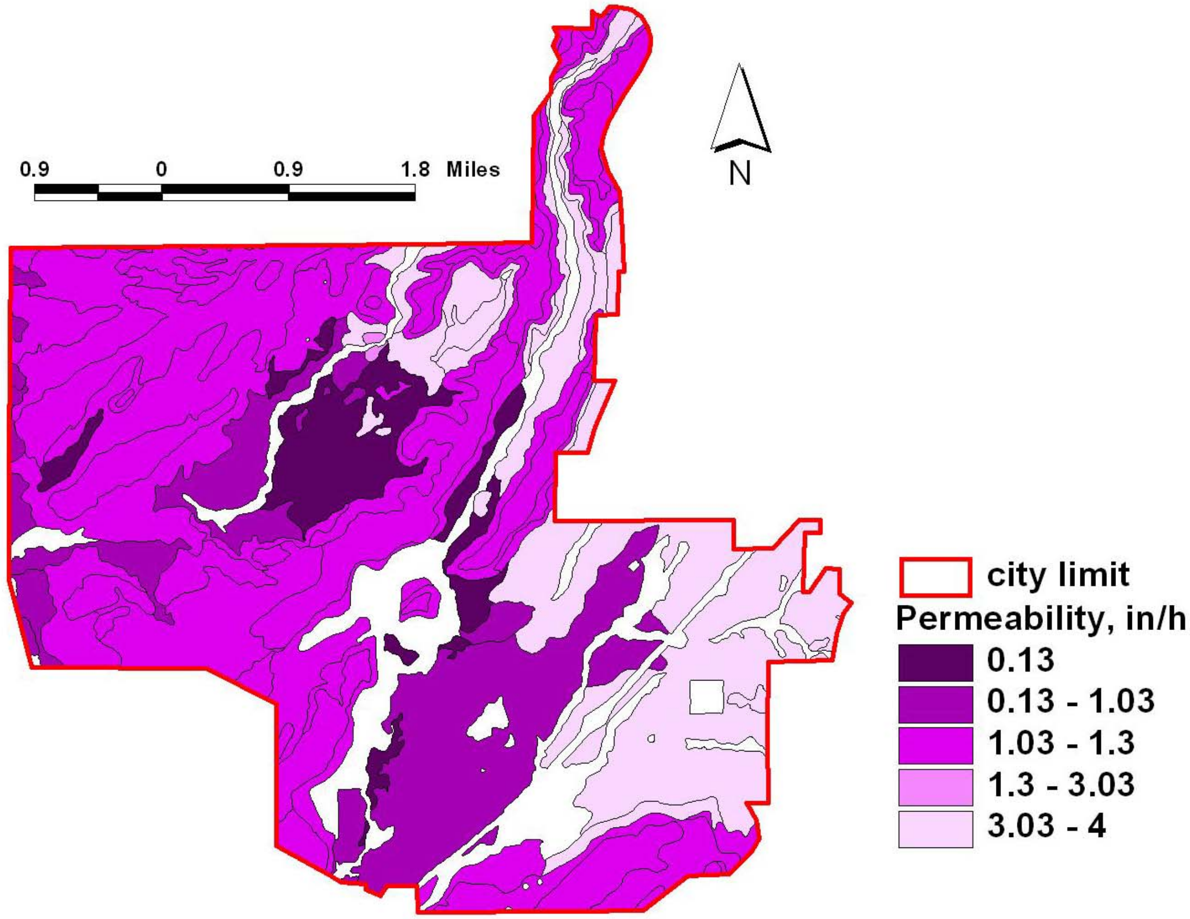

Figure 6-7. Distribution of soil permeability rates (in inches per hour) in Rocklin. Permeability is the rate at which water enters the soil. The lowest permeability rates are shown in the darkest color. Data is lacking or highly variable in white areas.

Some trees, including riparian species such as willows and cottonwoods, are adapted to growing in water or flooded soils. Many of these species develop specialized air channels within their roots that compensate for the lack of oxygen in the water. In areas with chronic high water tables that occur within 1 or 2 feet of the soil surface, only tree species that tolerate flooding and soil saturation should be used. A broader range of trees can tolerate seasonal soil saturation. For instance, the native valley oak can tolerate winter flooding, although it does not tolerate prolonged flooding during the growing season.

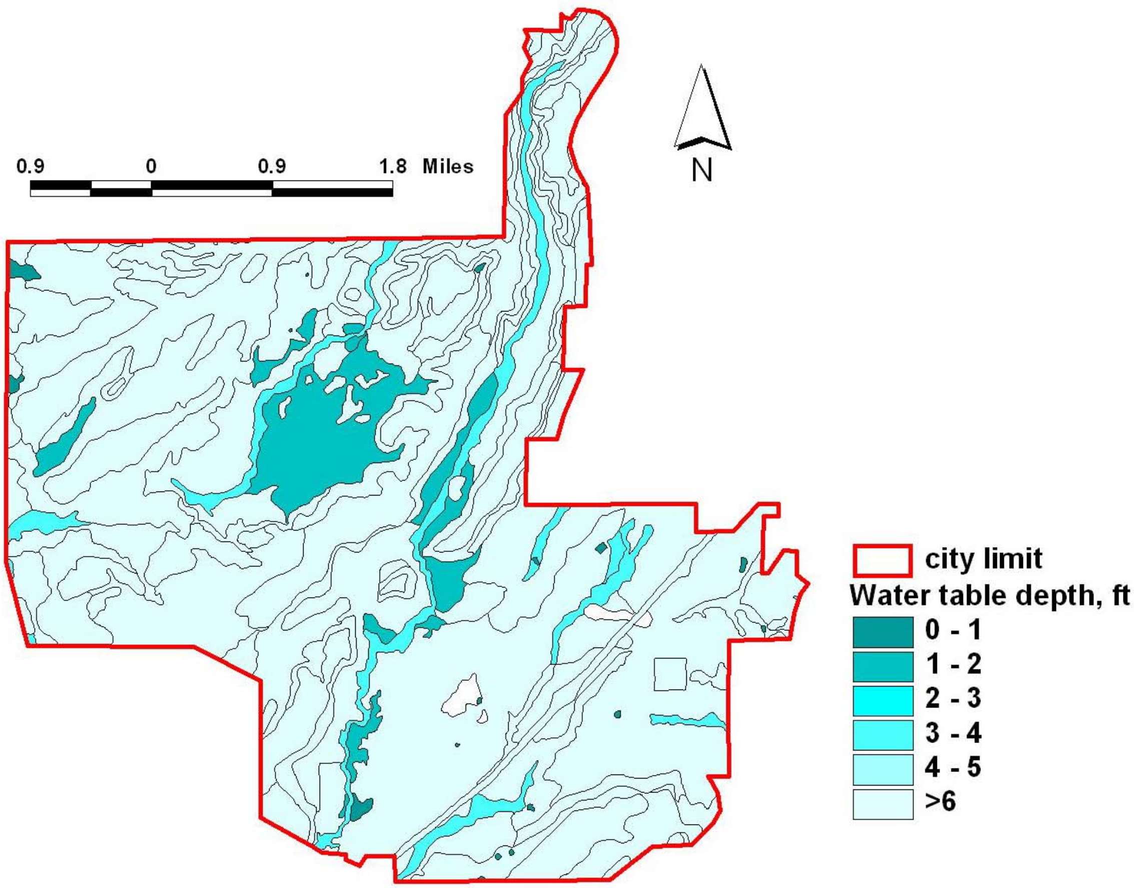

Figure 6-8. Distribution of water table depths (in feet) in Rocklin. Water tables shallower than about 2 feet (darkest colors) have the greatest negative impact on tree growth. Data is lacking or highly variable in white areas.

Soil compaction

Soil compaction decreases soil permeability rates, especially in soils with high clay contents. Compaction also inhibits root growth directly. Root growth typically becomes restricted when soil compaction reaches 80 to 85% of maximum compaction. Note that soils are typically compacted to 90 to 95% of maximum for engineering purposes in developed areas. Although some tree species are somewhat more tolerant of compacted soils than others, all trees perform best in soils that are not excessively compacted. Hence, most soils that have been graded for building purposes should be decompacted through tillage to improve conditions for tree growth.

In areas that have already been compacted that are to be planted with trees, compaction should be eliminated to a depth of at least 18 to 24 inches below final grade. Wherever possible, compaction should be relieved within the entire planting bed to this depth. Mechanical tillage of some sort is needed to break apart compacted soil. This can be accomplished with various types of equipment, including rippers, backhoes, trenchers, plows, and rotary tillers. It is also critical that the soil be at the correct soil moisture level for tillage to be effective. The fracturing effect of rippers is most effective in fairly dry soils, whereas rotary tillers are most effective in moist but not wet soils. Soils can be irrigated if necessary to increase soil moisture to a proper level for effective tillage. In other cases, tillage may need to be postponed, especially during the wet season, until soils are dry enough to work. In areas that lack existing vegetation, planting a cover crop of winter annual grasses can help to speed drying of the soil for subsequent tillage while at the same time providing organic matter that improves soil structure.

Soil compaction is most likely to occur when soils are wet. Compaction of wet soils can be minimized by avoiding foot and equipment traffic. At minimum, restrict such traffic to specific tracks if possible to minimize the area that becomes compacted. Plywood or thick layers of mulch can also be used to protect soil in localized areas from compaction by vehicles.

Soil pH

The relative acidity or alkalinity of the soil affects trees' ability to absorb mineral nutrients necessary for growth. The availability of most soil nutrients is greatest in soils that are neutral (pH 7) to slightly acid (pH less than 7). Fortunately, most native Rocklin soils are in this range. Almost all Rocklin soil types have a reported pH in the range of 5.1 to 7.3. The only exceptions are the clay Alamo soils (104 and 105 in Table 6-3) which can be slightly alkaline, up to pH 8.4. At this pH, alkaline-intolerant species may show yellowing symptoms ("lime-induced chlorosis") associated with low availability of iron and some other nutrients. Lime is sometimes applied to wet soils to stabilize them during construction, which can also result in excessively high soil pH levels in some sites.

In sites with high soil pH, use alkaline-tolerant species or use organic soil amendments and/or soil sulfur to decrease soil pH. Sulfur should be used with caution to avoid causing an excessively fast change in soil pH, which could injure existing plants. It is best applied some time prior to planting. Organic amendments change soil pH more gradually and can generally be applied safely around existing plants.

6.5. Tree planting methods

Tree planting holes

Depth

Planting trees too deep is a common problem in landscapes that can result in poor tree establishment. The objective is to plant the tree so that the uppermost roots that emerge from the trunk are at the final soil surface in the landscape after settling has occurred. For this reason, the center of the planting hole should not be dug any deeper than the height of the actual rootball. Because additional soil may have been added to the top of a container-grown tree in the nursery, check to find where the uppermost roots emerge from the trunk rather than using the soil level in the container as the guide for planting depth. To account for soil settling, the top of the actual rootball should be set slightly above the final grade and covered with mulch to prevent it from drying out.

Width

While all authorities agree that the depth of the planting hole should be no greater than the rootball depth to prevent settling, published recommendations for the width of the planting hole vary. Published recommendations for the widths of the planting hole range from 1.5 to at least 5 times the width of the root ball, generally with wider holes recommended for compacted soils. Recent standards put forth by the International Society of Arboriculture (ISA), American Forests, and other organizations recommend the use of wide planting holes at least 3 to 5 times the rootball width. Because soils in the developed portions of Rocklin are typically compacted due to mass grading of sites prior to construction, developing a wide area of noncompacted soil around newly planted trees is critical for good trees establishment and growth.

Other than providing a hole large enough to spread out the roots in the root ball itself, the main function of the planting hole is to reduce soil compaction in the rootzone. As such, an open hole does not have to be created except in the center of a tree planting site, and that open hole generally does not need to be more than 2-3 times the width of the root ball to permit the roots to be spread out properly. However, especially in compacted soils, soil compaction should be relieved in an area around the open planting hole. The total prepared area (open hole plus decompacted soil) should extend out at least 4 to 5 times the width of the container, and should be no less than 4 to 6 feet regardless of container size (Figure 6-9). This provides a zone where the new tree's roots will be able grow easily, and will allow it to establish its important buttress roots.

To eliminate excess soil compaction in the zone around the open planting hole, it will suffice to till the soil to a depth of about 12-18 inches by any method that will reduce the level of compaction. Root growth is inhibited at soil compactions that are about 80% of maximum, so tillage should reduce compaction to about 70-75% of maximum or less. Excavating and backfilling soil is acceptable as long as clods are broken up. For individual trees planted in yards or similar situations, the soil can be spaded in the same way that a garden bed would be prepared. Other tillage equipment, including trenchers, rippers, soil augers, or rotary tillers, if used correctly, may be used to achieve the same end effect. If compaction extends well beyond the upper foot of soil, it may be necessary to remove at least 6 to 12 inches of soil, till the subsurface soil to a depth of 18 inches or more, and reapply the surface soil. For tillage to be effective, soil moisture must be in a favorable range. The optimum soil moisture for tillage varies somewhat depending on soil type. In general, soil that is somewhat moist but not wet is easiest to till properly. Soil should be dry enough that it doesn't readily fuse into solid aggregates when compacted lightly, but should be wet enough that clods will fracture readily.

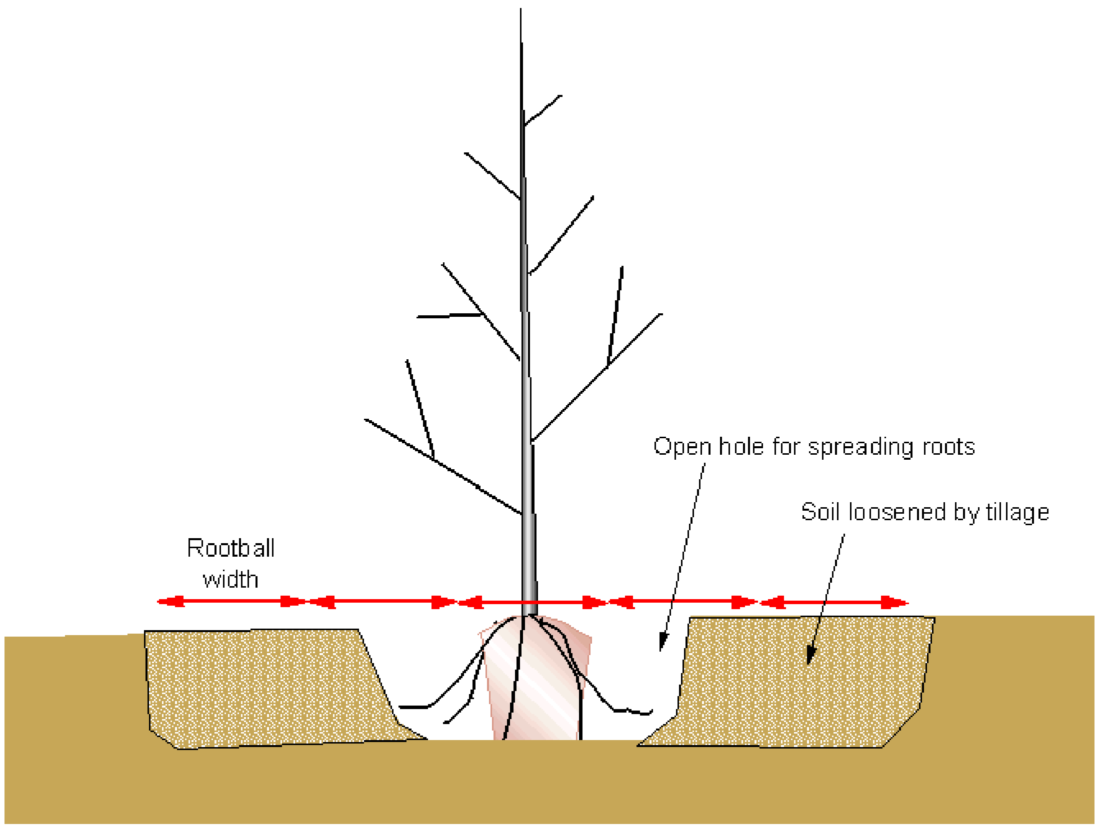

Figure 6-9. Schematic of planting hole and tree placement. The true soil line of the tree (i.e., typically where the first roots emerge from the stem should be set slightly above the final grade on firmed soil. An open hole for spreading roots should be 2 to 3 times the rootball width. The soil should be decompacted to at least the depth of the rootball (12-18 inches minimum) for a distance equal to at least 4 to 5 times the rootball width (red arrows).

Backfilling the planting hole

Unless the native soil at a site is unsuitable for plant growth, planting holes should normally be backfilled with the unamended, decompacted native soil taken from the hole. Various studies have shown no benefits and some detrimental effects of heavily amending the backfill soil with organic materials. Because organic materials decay over time, excessive settling can also occur in soils that are heavily amended with organic materials.

Using backfill soil with soil of a texture other than the native soil can lead to problems maintaining acceptable soil moisture levels. Due to capillary forces, water moves from coarser to finer soils. This can cause coarser sandy soils to dry out if they are adjacent to finer clayey soils. Interfaces between coarse and fine textured soils can also impede water flow, which may lead to saturated conditions in the planting hole.

Staking

If the top of a new tree is properly sized relative to its rootball, it should not require any staking. However, much of the commonly available nursery stock, especially large nursery stock, is grown to develop excessive tree height relative to the size of the rootball. Nursery stock that needs to be staked to support the weight of the canopy in full leaf should be rejected. Similarly, stock with tops that are overly large relative to the size of the rootball should not be used. Smaller, properly proportioned nursery stock will become established faster and will require less maintenance than larger stock with undersized rootballs. Furthermore, the smaller stock will typically surpass the size of the larger stock within a few years.

Newly-planted trees should only be staked if necessary, and stakes should be removed within a year after planting. Trees can be damaged by both improper staking and leaving stakes and ties in place too long. In addition, various studies have shown that trees will establish more quickly and develop stronger trunks and root systems if they are not staked at planting.

Any stake that has been used to secure the tree while it is in the original container should be removed at planting. If the tree is stable, staking is not needed. This is more likely to be the case for smaller trees. If staking is necessary, the height to place the ties can be determined as follows:

1. Hold the trunk with one hand and find the lowest height at which the unsupported top can stand up on its own.
2. Test this support point by using your other hand to flex the top of the tree lightly. The top should spring back to a vertical position and not remain deflected.
3. Position wide, flexible support ties (do not use wires, including wires with garden hose) about 6 inches above the support point determined through steps 1 and 2.

Ties should not be rigid, but should allow for some movement and flexing of the trunk, which stimulates the tree to develop taper. A loose-fitting figure-eight pattern around the stem cushions the tree from rubbing against the stake and allows for some movement. Use two stakes, placed in a line perpendicular to the prevailing wind direction. Stakes should be driven beyond the container root ball. Cut stakes off about 2 inches above the ties to keep the trunk and branches from rubbing on the stakes. Some manufactures have developed flexible stake/tie systems that use a single stake but allow for stem flexing as would occur in the two stake system. Regardless of the staking system used, it should remain in place the minimum time needed to allow tree to achieve stability, normally no more than one year, and should be placed no higher on the trunk than is necessary for stability.

If stakes or fencing are needed around the tree to provide protection from people, pets, other animals, and/or equipment, the stakes or fencing should be far enough from the stem to allow it to flex in the wind without rubbing on the hardware.

Mulching

Organic mulches applied to the soil surface under trees can provide many benefits. Mulches can:

- help conserve soil moisture by reducing evaporation,
- improve water infiltration into the soil,
- reduce summer soil temperatures, making them more favorable for root growth,
- suppress weed growth,
- improve soil structure;
- reduce compaction from foot traffic;
- reduce the likelihood of damage to the base of trees from lawnmowers;
- reduce soil erosion, and
- serve as a source of some plant nutrients as it slowly breaks down.

Around newly planted trees, mulch should be applied in a layer 2 to 3 inches thick to an area that extends in a circle 4 to 6 feet or more in diameter. For established trees, the mulched area can be extended to as much of the area beneath the canopy as is practical. In all cases, the mulch layer should thin out to a half inch or less immediately adjacent to the trunk. For mature existing trees such as oaks, it is best to avoid placing mulch within about 6 inches of the trunk. Because organic mulches break down over time, they need to be reapplied periodically to maintain desired depths.

In areas that are subject to chronic waterlogging due to high moisture tables, mulch should be kept thinner, no more than 1-2 inches, or should not be used at all if it exacerbates problems associated with excessive moisture.

Rock of varying sizes, from gravel to large cobbles ("river rock") is sometimes applied beneath new or existing trees in landscapes. Such materials may help protect against soil erosion but otherwise do not provide most of the benefits associated with organic mulches. Furthermore, rock "mulch" can have adverse affects on tree roots. Rock layers under trees absorb heat during the day and reradiate heat during the night, thereby increasing soil temperature and increasing the possibility of root damage and moisture loss, especially in a hot climate such as Rocklin's. Light-colored rock can also reflect sunlight, leading to elevated temperatures around the tree, which increases water use. In general, an organic mulch which is properly applied and maintained is likely to be superior to a layer of rock beneath new or existing trees.

Turf around young trees

Turf competes with tree roots for available water and nutrients. Some turf species also release chemicals into the soil that directly inhibit the growth of other plants. Especially for newly planted trees, turf close to the trunk can significantly reduce both root and top growth. Having turf close to tree trunks also increases the likelihood of damage to the trunk by mowing equipment.

Although various studies have shown that turf suppresses the growth of newly planted trees, it appears that the critical distance that should be kept clear of turf may vary somewhat according to the soil type, tree species, and/or turf grasses involved. As a general guideline, best growth will occur if the entire prepared planting hole area (open hole area + adjacent decompacted soil area = 4 to 5 times container width as noted above) is kept free of turf and is mulched.

One way to avoid having mulch work its way into turf is to excavate a shallow reverse bevel at the edge of the turf so that the mulch layer is no higher than the turf at the point that the two meet (Figure 6-10). Care should be taken to avoid making a depression around the base of the tree in which irrigation water will pool.

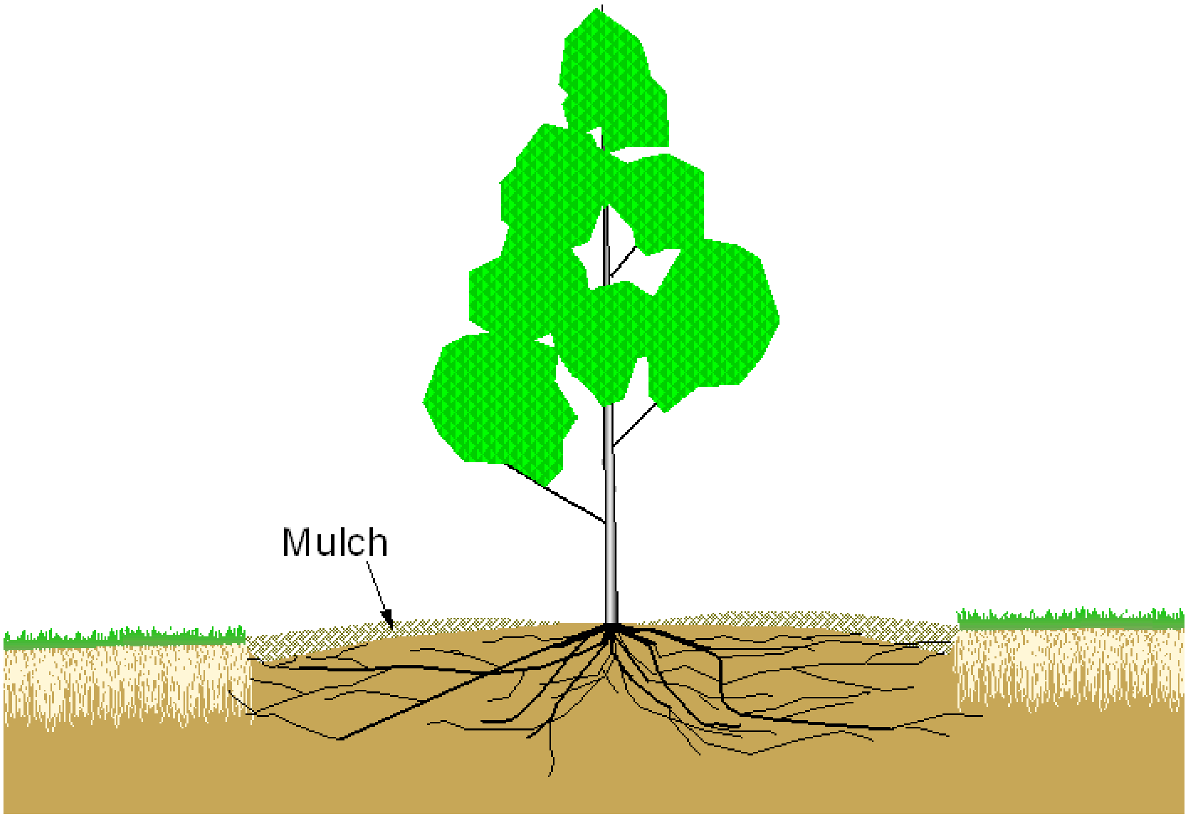

Figure 6-10. Schematic diagram showing grade alterations to allow for a clean interface between a mulched area around a young tree and surrounding turf. At the edge of the turf, the soil is cut down about 2-3 inches and beveled back to grade over a distance of about 18 inches. The mulch level should be just below mowing height at the edges, and tapers away to zero at the base of the tree. Note that the tree's root crown should be at or above the soil grade under the turf, so water will not pool there.

6.6. Irrigation

With the exception of locally native oak species planted directly from seed, almost all other trees planted in Rocklin are likely to require irrigation to become established. Many species will also require irrigation throughout the life of the tree in order to remain in good condition. Lack of sufficient irrigation and excessive irrigation are two of the most common causes of problems in urban trees. Proper irrigation practices require knowledge of:

- species' water needs, which can change as the tree becomes established,
- root distribution in the soil,
- soil characteristics, and
- seasonal weather patterns and recent weather conditions.

Where to irrigate

Newly planted trees

Because the root systems of newly planted trees are largely restricted to the original rootball, water must be applied in this area until new roots grow into the soil of the planting site. If the rootball area contains a high amount of coarse-textured potting soil, it may dry out faster than the surrounding soil. Therefore, frequent irrigation of the rootball area may be required until roots expand into the surrounding soil. This is more of an issue for trees planted in the spring and summer. Trees planted in the late fall or winter typically have a longer time for roots to grow into the planting site soil before water demand becomes high.

To encourage root expansion, water should also be applied to the area beyond the original root ball (Figure 6-11). However, because few roots will initially be present in this area, soil moisture in this zone should be monitored so that it does not become excessively wet.

As the tree becomes established and the root system expands, irrigation of the original root ball area should be discontinued and progressively wider areas around the tree should be irrigated. A newly planted tree may take 1-2 years to become established. Larger container stock trees may take longer to become established than smaller stock.

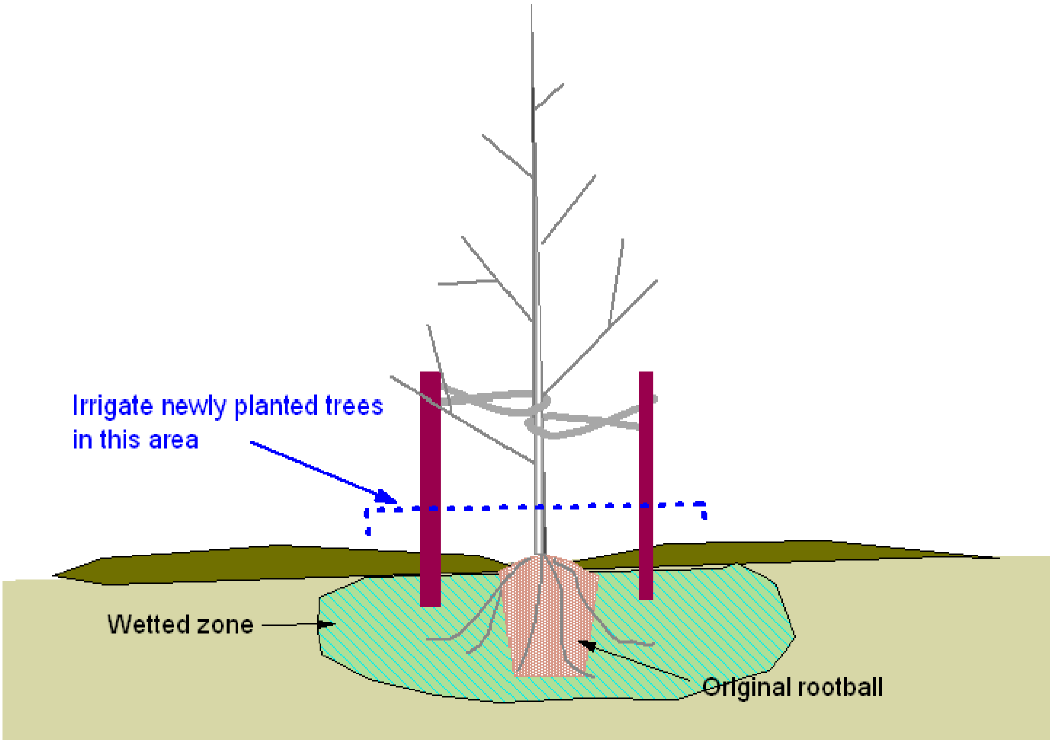

Figure 6-11. Schematic diagram showing the area to irrigate for newly planted trees. Initially, the original rootball area needs to be irrigated because most of the tree's roots are limited to that area. The soil mix in the original rootball may also dry out faster than the surrounding soil. Wetting the soil beyond the rootball will encourage root expansion into this area

Established trees

Mature native oaks, especially blue oak, normally do not need supplemental irrigation. Irrigation of these trees during the summer increases the risk of root diseases that will lead to the decline of the tree. At minimum, the entire area under the canopy of mature oaks should remain nonirrigated during the summer.

Mature trees that require or tolerate irrigation generally should not be irrigated directly adjacent to the trunk, because moisture in this area can increase the risk of disease. Roots of most established trees can extend far beyond the edge of the canopy or drip line. For most trees, it is preferable to irrigate in the outer half of the area under the canopy and beyond the edge of the canopy as shown in Figure 6-12.

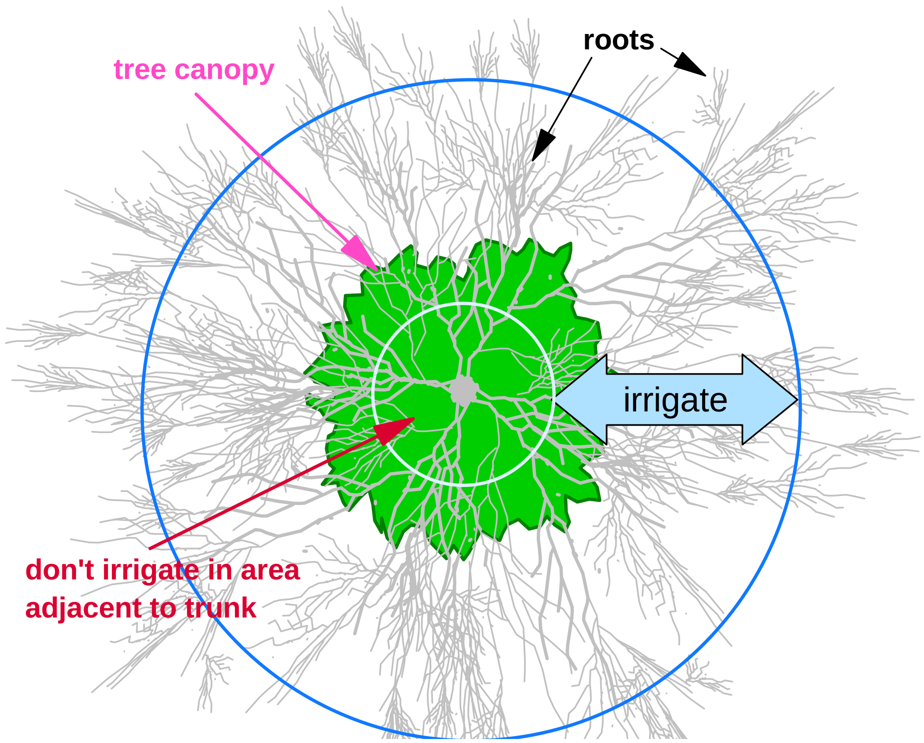

Figure 6-12. Schematic overhead diagram showing the area to irrigate for established trees that need or tolerate irrigation. Unless restricted by soil conditions, roots of most trees can extend outward at least 2 to 3 times the canopy radius. To minimize the potential for disease problems, the area near the trunk should generally not be irrigated.

How to irrigate

Irrigation can be applied effectively using various methods, depending on the topography and soil characteristics of the site. The following guidelines should be followed no matter how irrigation water is applied.

Water deeply rather than frequently. Because most tree roots are found in the upper 18 - 24 inches of the soil, this is the zone that should be wetted up in each irrigation cycle (Figure 6-13). Depending on the tree species water use (low to high) and soil water holding capacity (low to high), a single deep irrigation of the rootzone will meet a tree's water needs for a period ranging from about a week to several months during the summer.

Stop watering when runoff starts. Soils high in clay accept water slowly, less than 1/4 inch per hour in some cases (Figure 6-7). Water infiltration is especially slow in compacted soils. If water starts to pool or run off, stop irrigating, let the water soak in, and start watering again. Repeat on/off cycles until you apply enough water to wet the soil to 18-24 inches. This may take a number of cycles over several days.

Don't saturate the soil for long periods. Water displaces air in the soil, so long periods of soil saturation can suffocate growing roots. Take a long enough break between irrigation cycles to allow the free water to be absorbed. If in doubt, probe or dig to make sure that the soil isn't waterlogged below the surface.

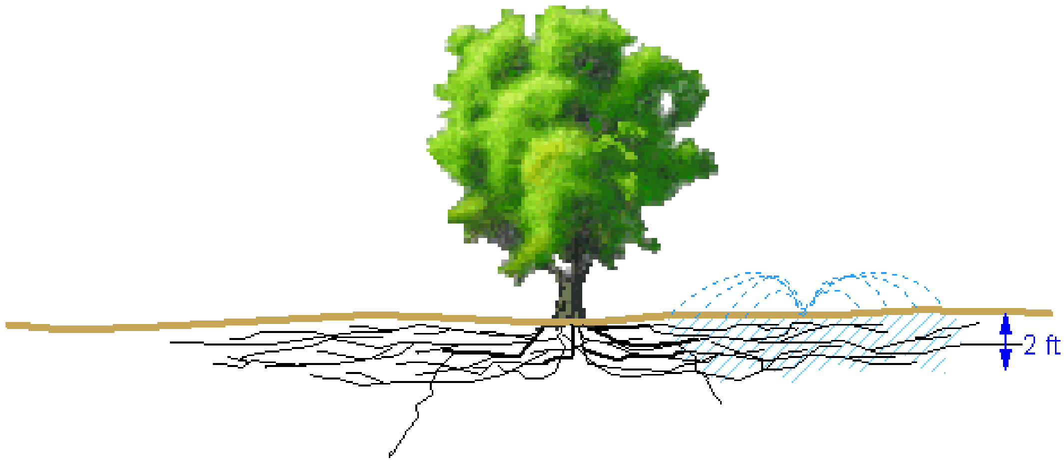

Figure 6-13. Schematic profile diagram showing the optimal area to irrigate for established trees that need or tolerate irrigation. Most tree roots are found in the upper 2 to 3 feet of the soil profile, although some go deeper, depending on soil characteristics. Irrigation should be applied to wet the soil to a depth of about 2 feet if possible. Diagram also shows how tree roots typically extend well beyond the tree's canopy.

How much water to apply

Tree irrigation needs change over time. The amount of irrigation a tree will need can be affected by:

- **Species** - Some tree species require no additional irrigation once established, whereas others will do poorly without consistent irrigation throughout the summer. Table 6-1 above includes ratings of relative water use by different species.
- **Tree age** - A newly planted tree will need more frequent irrigation than an established tree because its root system is more limited.
- **Root damage** - An established tree that suffers root loss or damage (for instance, due to trenching within the root zone) may need additional irrigation until new roots grow to replace those that are destroyed.
- **Time of the year** - The need for irrigation is greatest in mid to late summer, when temperatures are the highest and most of the moisture stored in the soil over the winter has been depleted.
- **Weather conditions** - In drought years, soil moisture is used up earlier in the season, so the period of peak water need is longer. Some trees that do not normally need irrigation may benefit from irrigation in drought years. In very wet years, irrigation may not be needed until early summer. During atypically hot periods, trees need more water. Trees need less water during cool and cloudy conditions.
- **Soil conditions** - Trees use water stored in the soil. Soil type, depth, and condition influence how much water can be stored in the soil, and consequently how often you may need to water. Soils that have more clay hold more water and can be irrigated less frequently. Sandy soils hold relatively little water and need more frequent irrigation. As shown in Table 6-3 and Figure 6-6, most Rocklin soils store between 1.25 and 7 inches of water that is available to trees.

Table 6-4 shows typical irrigation needs of trees with high, medium, and low water needs growing in Rocklin. Note that one inch of irrigation water is the equivalent of covering the area with a layer of water one inch thick. Over 100 square feet of irrigated area (a 10 by 10 feet square), one inch of irrigation equals about 62 gallons. The table shows that high water use trees may need at least four times as much irrigation as a tree with low water needs. Trees in especially hot, dry sites, such as parking lots or near heat-reflecting walls, may require up to 40% more water than is listed in Table 6-4.

Table 6-4. Typical irrigation requirements (inches of applied water per month) for high, medium and low water use trees in Rocklin under average weather conditions.[1]

	Inches of water		
Month	High water use	Medium water use	Low water use
March	1.5	0.3	0.0
April	3.5	1.8	0.1
May	6.0	3.7	1.3
June	8.2	5.4	2.7
July	9.2	6.2	3.1
August	8.2	5.5	2.8
September	5.9	3.9	1. 9
October	2.8	1. 5	0.1
Total	45.4	28.2	11.8

[1] Water use calculations assume irrigation system losses of 6%, irrigation distribution uniformity of 90%. After accounting for 70% allowable moisture depletion, the working rootzone water storage capacity is 1.68 inches. Calculations also assume average rainfall as reported by the Western Regional Climate Center and average reference evapotranspiration (ETo) as compiled by the California Irrigation Managemnt Information System (CIMIS).

6.7. Pruning

Training young trees

One of the most cost-effective management actions that can be taken to promote tree health and longevity is timely and proper pruning of young trees. Most pruning cuts needed to train a young tree are small and can be made with pruning shears or loppers by a person standing on the ground. These modest efforts have a large payback in terms of tree performance over the long term. Proper training will:

- **Improve structural strength** - branches that will be more prone to breakage as tree grows are removed so that the tree is less likely to have branch failures.
- **Reduce future maintenance** - good branch distribution and structure will reduce need for future maintenance and will make any needed maintenance easier.
- **Increase tree longevity** - properly trained trees are less likely to suffer branch breakage that can shorten tree life.

Even though the pruning cuts made on a young tree are mostly small and easy to make, considerable care should be exercised in deciding which branches to remove and in making proper cuts. Just as proper training can have positive impacts for the life of the tree, poorly placed and bad pruning cuts on a young tree can create long-term problems that may be difficult or impossible to correct. Incorrect pruning of trees in the nursery, before they are installed in the landscape, is a source of various common structural problems that can shorten the useful life of trees in the landscape.

Five steps for training young trees are summarized in Table 6-5 below and illustrated in Figure 6-14. It is important to avoid overpruning young trees, since this can retard growth and may lead to undesirable structural consequences. Don't remove any more branches than are needed to accomplish the five steps in Table 6-5, and don't remove more than about 1/4 of the tree canopy in a single year. Commonly, no more than 5% to 10% of the canopy needs to be removed in a given year during training.

Temporary branches along the lower stem are common in natural tree seedlings and saplings and serve several important functions. They help promote growth of stem caliper (diameter), which makes the tree more resistant to bending and possible breakage. They also shade the lower trunk, reducing the risk of sunburn, promote overall growth of the tree, and can protect the young trunk from damage by animals or vandals. Nurseries have traditionally removed these branches primarily for the sake of appearance. However, this practice results in trees that are weak due to an abnormal lack of stem taper (i.e., the progressive increase in stem diameter toward the base of the tree). Conserving temporary branches on the trunk of young trees can be an effective way to promote the establishment of young trees.

Other sources, including the ISA website (http://www.treesaregood.com/treecare/pruning_young.aspx) and the Urban Tree Foundation website (http://www.urbantree.org/training_young_trees.asp) provide additional information on training young trees.

Table 6-5. Five basic steps for training young trees.

Step	What	When	How
1.	Remove broken, diseased, dying, or dead branches	Start at planting and repeat as necessary	☛ Remove only as much as needed to correct the problem. ☛ Avoid leaving stubs and cut back to the point of branch origin or to a bud on small twigs.
2.	Select a central leader and remove competing leaders	Start at planting and repeat as necessary	☛ Generally the strongest and most vertical stem should be selected as the leader
3.	Select the lowest permanent branch	By the fourth or fifth year after planting; need to wait until tree is tall enough	☛ Height is based on necessary clearance: typically 8 ft over sidewalks. ☛ A bit of nylon string can be tied around the stem to mark the branch for future reference.
4.	Select main (scaffold) branches and remove or cut back competing branches	After lowest permanent branch is selected	☛ Distribute main branches around the trunk evenly on all sides. ☛ Space main branches 12 to 18 inches apart up and down the trunk - use larger spacing for trees that have greater mature height. ☛ Main branches should be no more than half the size of the trunk at the attachment point and should not contain included bark (bark that becomes pinched between branches that diverge at a narrow angle) ☛ Lateral branches along the main branches should not be located closer than 2 feet from the trunk
5.	Select and maintain temporary branches below the lowest permanent branch	Starting at planting	☛ Remove temporary branches that: - become 1½ inches in diameter - are 1/3 the size of the main stem at the point of attachment - are within about 4 inches of selected scaffolds ☛ Shorten temporary branches to suppress them

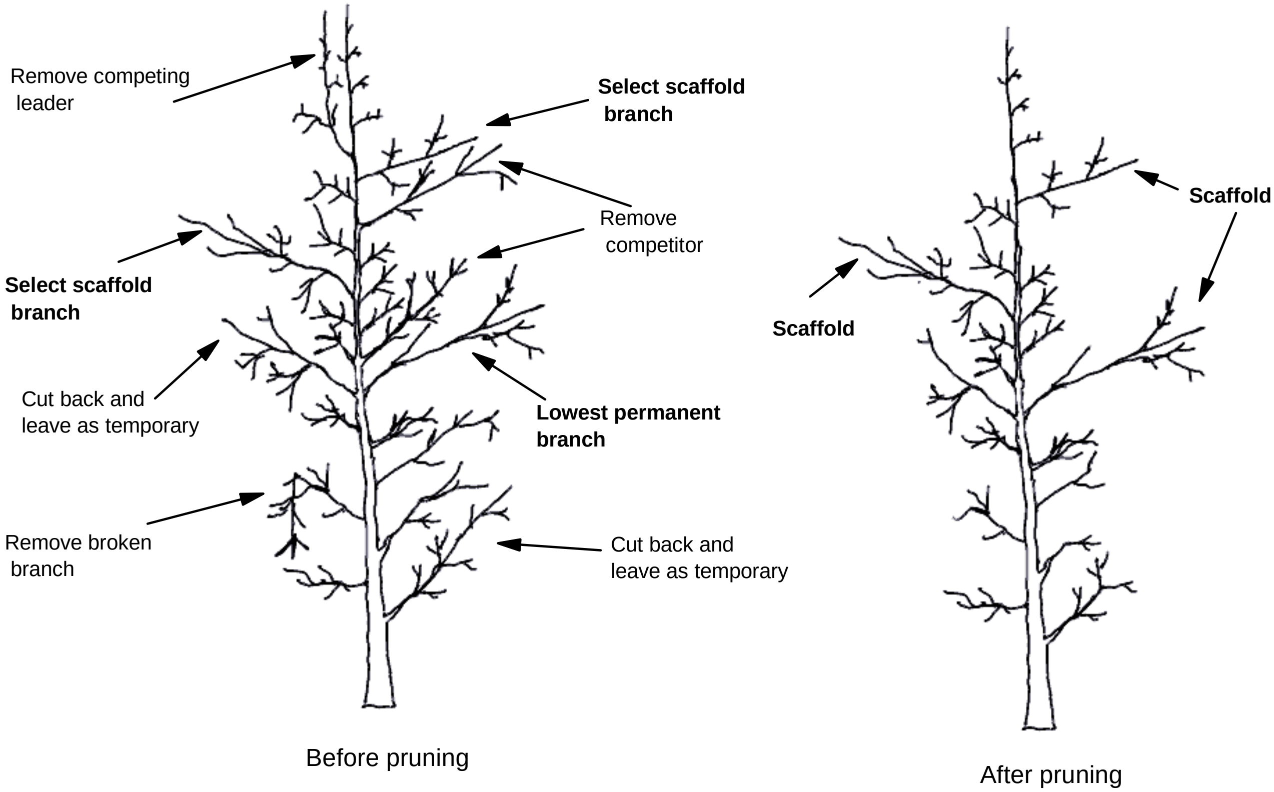

Figure 6-14. An example of pruning on a young tree. After the lowest permanent branch has been selected, well spaced scaffold branches (distributed around the stem) are identified. Temporary branches are left in place but are cut back to suppress their growth. A competing leader and branches that will compete with the permanent branches are removed. Broken, dead, and crossing branches would also be removed at this time.

Mature trees

Mature trees may require pruning for various reasons. Improving tree safety is one of the most common and important reasons for pruning trees. Safety pruning targets branches that have a high risk of breaking because they are dead, decayed, or structurally weak. A different type of pruning related to safety involves increasing clearances and clearing sight lines, especially near streets. In some cases, tree health can be improved and pest/disease spread can be reduced by removing diseased or insect-infested branches. Pruning can also be used to modify the appearance of trees and to encourage fruit or flower production. However, each pruning cut has the potential to alter tree growth and creates a wound that has the potential to serve as an entry point for wood decay organisms or other pests and diseases. Hence, unnecessary pruning should be avoided.

Proper methods for pruning mature trees can be found in a variety of sources. The ANSI A300 standards provide standard pruning specifications for professionals and can be purchased directly from ANSI or through organizations such as the ISA. A guide to pruning produced by the Northeastern Region of the USDA Forest Service is available online (http://www.na.fs.fed.us/spfo/pubs/howtos/ht_prune/prun001.htm) and has been attached in

Appendix 7.9. The following sections summarize only a few of the key factors related to pruning.

Limits of pruning

Removal of live branches stresses trees by reducing leaf area, creating wounds, and possibly exposing other branches to sunburning. For these reasons, no more than about one-quarter of the live foliage area should be removed from a tree in a year. If additional pruning is needed to achieve specific pruning goals, it is preferable to defer additional pruning to a subsequent year. If trees are properly trained when young and subsequently inspected and pruned as needed in a timely manner, it should not be necessary to remove large amounts of live branches in a single pruning. Note that there is no need to limit to the amount of dead branches that are removed in a single pruning.

Individual branches will also tend to decline if they are excessively pruned. For this reason, if more than half of the live foliage must be removed from an individual branch, the entire branch should generally be removed.

When to prune trees

The best time to prune can vary somewhat by species. It is best to prune most trees during the dormant season (December to February), or as close to the dormant season as possible. Avoid pruning during the spring growth flush. Light pruning and removal of dead wood can usually be done at anytime.

The main exception to the above guidelines is that mature native oaks are best pruned during the dry season (late spring to late summer) to reduce the chance that decay fungi will invade new pruning wounds. Most decay fungi sporulate during the wet season, beginning in the fall, so spores are most likely to fall on and colonize fresh pruning wounds over the wet season. Most published pruning guidelines do not include this exception, which is appropriate for California's Mediterranean climate but does not make sense in areas that get summer rainfall.

Proper pruning cuts

The wound created by a pruning cut will close as callus tissue that forms around the edges of the cut grows to cover the cut surface. A properly placed pruning cut will callus over in the minimum amount of time and will be less likely to become decayed. However, wound closure will take longer for larger pruning cuts, even if properly made. Hence, proper training of young trees to develop strong and well-placed branches is the key to avoiding large pruning cuts in mature trees.

For a lateral branch, a properly-placed pruning cut is placed near the point where the branch emerges from the main stem. The branch should not be cut off flush with the stem, nor should a stub be left (Figure 6-15). The slight swelling at the base of a branch where it joins the main stem is called the branch collar. A properly-placed cut is at the outer edge of the branch collar, which typically angles away from the trunk somewhat (Figure 6-16). If the main stem has callus developing around the base of a dead branch, the dead wood is removed without cutting into the existing callus.

If a lateral branch has no obvious branch collar, the placement of the cut starts just beyond the branch bark ridge, which is an irregularly raised or thickened area of bark that forms in the branch crotch and may extend part way around the main stem. The cut starts outside the branch bark ridge and angles outward along a line that is close to perpendicular to the long axis of the removed branch (Figure 6-16).

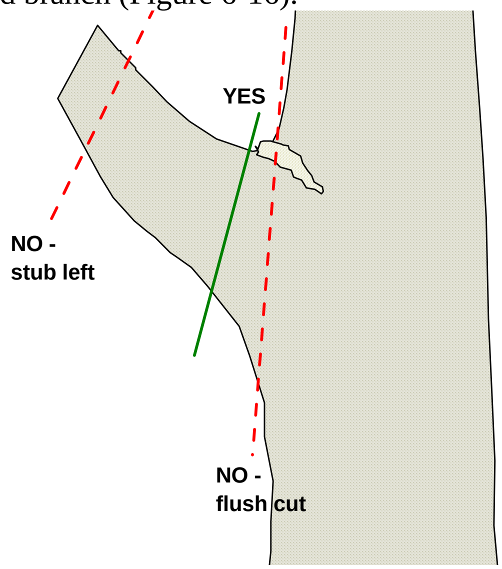

Figure 6-15. The wound created by a properly placed pruning cut will close as callus tissue around the edges of the cut grows to cover the cut surface. Stubs that are left from cuts that are placed too far from the main stem typically die and may decay without being closed by callus tissue. Flush cuts made parallel to the main stem create a larger wound than a proper cut. Wound closure on flush cuts is further delayed because natural barrier zones near the base of the branch that aid wound closure are cut away.

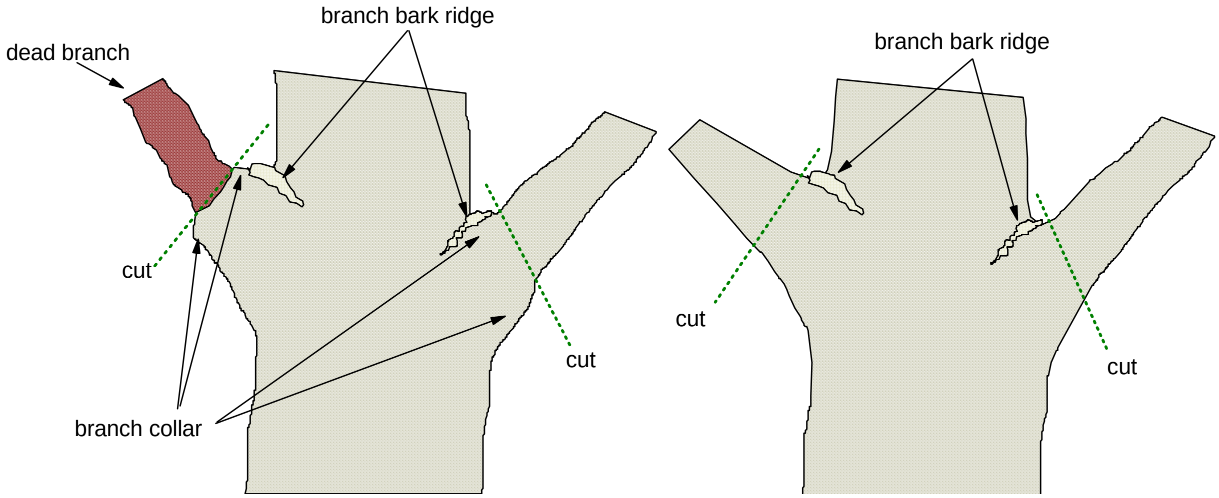

Figure 6-16. Properly placed pruning cuts are made just to the outside of the branch collar (left). In trees that do not have an obvious branch collar, the cut is placed beyond the branch bark ridge and is nearly perpendicular to the long axis of the removed stem.

In cases where a larger stem needs to be cut back to a lateral branch, the cut is angled as shown in Figure 6-17. When cutting a main branch back in this way, place the cut next to a side branch that is at least 1/2 the diameter of the removed stem. If the lateral is too small to assume the dominant role previously provided by the main stem, dormant buds lower on the stem may produce an abundance of epicormic shoots along the stem and/or the stem may die back, leaving a stub.

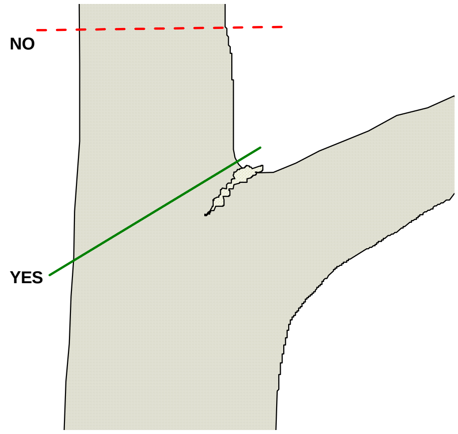

Figure 6-17. Cutting back a main stem to a sufficiently large lateral branch is also known as drop crotch pruning. The final cut on the main stem is made to the outside of the branch bark ridge angled away from the branch at close to a 45 degree angle. The lateral must be large enough to serve as the new leader, generally at least 1/2 the diameter of the removed stem.

To prevent the bark from tearing away when branches are cut off with a saw, three cuts should be used (Figure 6-18). The first cut is made part way into the branch on the underside about a foot from the area where the final cut will be made. The second cut is made through the branch from the top and will cause the branch to break off along a line between the first and second cuts. A third and final cut is made to remove the remaining stub along the proper cut line. Especially if the stub is heavy or large, it may still have to be supported to ensure that it doesn't tear the bark off the main stem as it begins to fall.

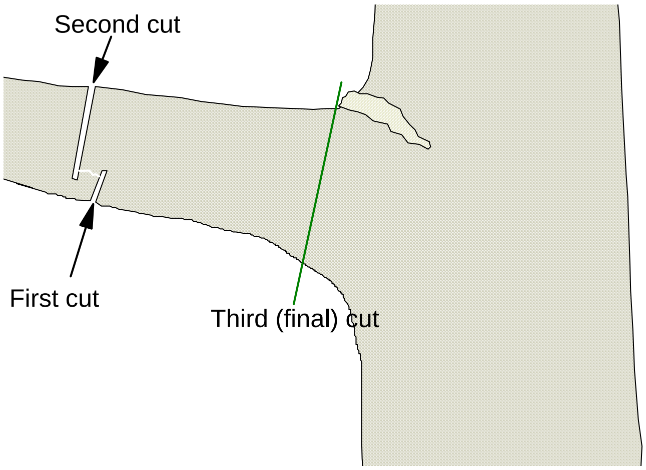

Figure 6-18. To prevent bark from tearing off the main stem as a branch is cut off, three pruning cuts are used when trimming off a branch. The first cut is made on the underside of the branch to be removed. The second cut is made slightly beyond the first cut and removes the branch. Commonly, the branch will fall when a fracture develops between the first and second cuts before the second cut passes through the entire branch. The final cut is made to the outside of the branch bark and branch collar (if present) as shown in Figure 6-16 above. It may be necessary to support the stub when making the final cut to prevent bark from being peeled off the main stem.

Improper pruning

Topping (cutting large branches back to stubs) is an unacceptable pruning practice that adversely affects tree health and safety. Topping typically removes large amounts of the leaf-bearing crown of the tree (50 - 100%). This seriously weakens the tree, and can lead to branch decay and possibly tree death. After topping, trees respond by producing excessive numbers of fast growing shoots from latent buds. These sprouts are poorly attached to the stubbed branches and develop into branches that are prone to break off, especially in high winds. Topped trees require more maintenance than properly-pruned trees. Corrective pruning is required to make topped trees less hazardous, but can never really restore the tree to its previous form.

Another improper pruning practice is known as stripping or lion-tailing. It involves the removal of all side branches along a limb except for a tuft at the end. The denuded branch with a tuft of foliage at the end resembles a lion's tail. This practice leads to branches with excessive end weight and suppresses the normal thickening of the stem along its length (taper). Such branches are prone to splitting or breaking. As with topping, it may be difficult or impossible to restore the structure of a lion-tailed tree.

6.8. Sources of information on tree planting and maintenance

International Society of Arboriculture - http://www.isa-arbor.com

The ISA provides a wide variety of tree care information at their website. Most of the information is up to date, but since the site is intended for users throughout the US and other countries (mostly in temperate areas), not all information is entirely appropriate for Rocklin's Mediterranean climate. Also, contributed material comes from multiple sources and recommendations on various parts of the site may vary slightly. Online information is available at:

http://www.treesaregood.com/treecare/treecareinfo.aspx – This is a subsection of the ISA site that is tailored more directly toward tree owners. Information is provided on planting, pruning, mulching, managing trees in turf, tree damage due to construction, tree hazards, and other topics.

http://www.isa-arbor.com/publications/cadDetails.aspx – This area of the ISA site includes landscape architectural specifications and CAD specifications (in DWG and DWF formats) for tree planting, tree staking, and soil preparation.

American National Standards Institute - http://www.ansi.org/

ANSI is an accrediting organization that publishes standards developed by other organizations. The ANSI A300 Standard and the ANSI Z133 Standard are two voluntary standards related to tree pruning that have been developed by tree care professionals.

<u>ANSI Z133.1 (2000) Pruning, Trimming, Repairing, Maintaining, and Removing Trees, and Cutting Brush — Safety Requirements.</u> These are industry standards for safe work practices related to tree maintenance work. This standard is currently being revised.

<u>ANSI A300, Part 1 (2001) Tree, Shrub, and Other Woody Plant Maintenance - Standard Practices.</u> This document provides standard definitions for tree care maintenance, performance standards for tree pruning operations, performance standards for utility line clearance, and performance standards for writing tree pruning specifications. Two other related standards are ANSI A300, Part 2 (1998) on Tree Fertilization and ANSI A300, Part 3 (2000) on Tree Support Systems (Cabling, Bracing and Guying).

Copies of the standards may be purchased from various sources, including:
ANSI (http://webstore.ansi.org/ansidocstore/default.asp)
Tree Care Industry Association (http://www.treecareindustry.org/)
ISA (http://secure.isa-arbor.com/store/)
Western Chapter of ISA (http://www.wcisa.net/)

Urban Tree Foundation - http://urbantree.org/

This site is the source of the Guideline Specifications for Nursery Tree Quality included in Appendix 7.8. It also has information on tree planting, tree selection (including tree lists) and pruning.

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