

# **AN EVALUATION OF PHOSPHORUS CONTRIBUTIONS TO CHERRY CREEK RESERVOIR FROM ON-SITE SEWAGE DISPOSAL SYSTEMS**

## **PHASE I**

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Cherry Creek Basin Authority**

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## INTRODUCTION

### Background:

In 1984 the EPA Clean Lakes Study was completed for Cherry Creek Reservoir. This Study concluded that there was a potential for accelerated eutrophication to occur in the reservoir and that impairment to beneficial uses could result. Phosphorus was identified as the major limiting nutrient to algal production. In response to this study the Colorado Water Quality Control Commission (Commission) established an in-reservoir total phosphorus standard of 0.035 mg/l. The intent of this standard was to maintain the chlorophyll-a level in the reservoir below 0.015 mg/l.

To maintain the established standard and to preserve the beneficial uses of the reservoir, local entities within the Cherry Creek Basin undertook the cooperative effort of preparing a water quality management master plan (Master Plan) for the basin. This Master Plan was completed in September of 1985. The Commission adopted portions of the Master Plan as regulation on November 6, 1985. The Cherry Creek Basin Authority (Authority) was also formed in the fall of 1985 by inter-governmental agreement to coordinate and implement the tasks set for in the Master Plan.

## Master Plan Septic System Phosphorus Allocation

The Master Plan made the determination that 14,270 pounds per year of phosphorus could enter the reservoir without causing the 0.035 mg/l phosphorus standard to be exceeded. A major component of the plan involved allocating these 14,270 pounds to the various sources of phosphorus in the Basin.

As a part of the allocation process, it was projected that the population in the basin served by septic systems would be 19,400 people by 1990; 36,800 by 2000; and 52,600 by 2010. These population projections were then utilized in conjunction with an estimated average septic system phosphorus effluent concentration of 0.058 mg/l to project future septic system phosphorus loadings as follows:

Table 1  
Projected Future Phosphorus Loading From  
Septic Systems

<u>Year</u>	<u>Estimated Annual</u>
	<u>Load, lbs</u>
1990	260
2000	450
2010	700

Based upon this analysis the Master Plan and subsequent Control Regulation allocated 450 pounds per year to septic systems.

#### Master Plan Septic System Policy

An integral part of the Master Plan is a control program to ensure that the phosphorus reservoir standard is maintained. This program set forth a strategy to deal with both point and nonpoint sources of phosphorus. One component of the nonpoint control program is the adoption of Best Management Practices (BMP's). The Plan identified "erosion control regulations and septic regulations" as two non-structural BMP's that are critical in helping meet allowable phosphorus loads.

The Master Plan identified the following as reasons for regulating the phosphorus contributions of septic systems in the basin:

1. Based upon large lot population projections in the basin, significant quantities of phosphorus could be generated from this source.
2. The implementation of BMP's through septic regulations could possibly keep this source of phosphorus to a minimum.
3. If point sources and other nonpoint phosphorus

sources must be regulated, it followed that septic systems should meet certain phosphorus performance standards.

In relation to the ultimate adoption of BMP's through septic regulations the plan made the following recommendations:

1. Douglas and Arapahoe Counties should work with Tri-County Health Department to develop regulations as soon as possible requiring phosphorus performance criteria for septic systems.
2. The counties, Basin Authority and Tri-County should be responsible for initiating a research program to quantify existing loadings from septic systems, to evaluate soil types in the Cherry Creek Basin, and to evaluate other factors such as location of systems within the Basin.

#### Phosphorus Study

To implement the recommendations of the Master Plan, Tri-County proposed to the Basin Authority a four phase study of phosphorus contributions to Cherry Creek Reservoir from septic systems. The scope of work for this study is included in Appendix D. The Basin Authority agreed to fund Phase 1 of this Study.

The objective of Phase 1 is to provide a preliminary assess-

ment of current and future phosphorus contributions to Cherry Creek Reservoir from septic systems. This preliminary assessment is based upon existing data relative to basin soils, geology, hydrology and does not include any onsite field investigations or laboratory testing which will be necessary to validate numerous assumptions. Loading projections were obtained by:

1. Utilizing existing data to assign basin soils a Phosphorus Removal Classification.
2. Projecting probable ranges of phosphorus removal for each soil type.
3. Determining the approximate number of present and future residences in each soil classification.
4. Estimating present and future loadings. (Based upon 2 & 3 above).

Based upon the findings of Phase 1, the scope of work for future phases will be modified. In addition, the results of Phase 1 will be evaluated to determine if interim changes to Tri-County's septic system regulations are warranted prior to completion of the remaining phases of the study.



DEVELOPMENT OF  
PHOSPHORUS REMOVAL CLASSIFICATION  
SYSTEM

Introduction

The first step in preparing the preliminary assessment was to develop a phosphorus removal classification system. To initiate this process, the available technical reports relative to basin geology and the phosphorus cycle were reviewed. An extensive literature review was then conducted to provide background information relative to how phosphorus is retained in the soil. Based upon these data, three soil classes were developed for the Basin based upon their estimated phosphate retention capabilities. Finally, phosphorus retention percentages were assigned to each classification.

Overview Of Basin Geology

Prior to development of the phosphorus removal classification system, available technical reports relative to the geology of the Cherry Creek Basin were reviewed. The findings of this review are summarized below.

The geologic formations underlying the Cherry Creek Basin soils are the Castle Rock conglomerate, the Dawson arkose, the Denver, Arapahoe, and Laramie formations, the Fox Hills sandstone, and the Pierre shale (Robson and Romero, 1981).

The upper part of the Dawson formation forms most of the bedrock between Colorado Springs and Denver. This formation

consists of arkosic (high feldspar content) sandstone, siltstone, claystone, and conglomerate up to 2000 ft (610 m) thick (Scott and Wobus, 1973). The conglomerates and sandstones are generally coarse-grained (Robson, 1983).

From the Castle Rock area to the southeast through the Castlewood Canyon area and into Elbert County, Castle Rock conglomerate overlies the Dawson formation. This conglomerate is bouldery cobble gravel of Precambrian rocks well cemented by silica. Outcrops of Wall Mountain tuff, a fine-grained rhyolitic volcanic rock, are found south of Castlewood Canyon recreation area (Trimble and Machette, 1979a).

Large areas adjacent to streams in the Cherry Valley School area of southeast Douglas County are part of the Slocum alluvium, bouldery cobble gravel which contains calcium carbonate in the upper layers. This alluvium is generally less than 25 ft. (7.6m) thick.

Most of the alluvium in stream valleys within the basin is Post-Piney Creek and Piney Creek alluvium--gravel, sand, silt, and clay of stream flood plains and lower terraces not more than 20 ft. (6 m) above stream level (Trimble and Machette, 1979a).

Away from the stream valleys, in an area bounded on the east by Parker Road and on the west by I-25, on the south by Parker and on the north by Cherry Creek Reservoir, is colluvium (an unconsolidated material deposited by gravity and

wash) and loess (primarily windblown silt). Bordering  
r Road on the east, from the reservoir south to Parker  
large areas of windblown sand derived mainly from  
ium of the major streams (Trimble and Machette, 1979b).

allow bedrock in much of the upland area of the  
ern basin, and the coarse nature of much of the alluvial  
ial away from stream valleys would indicate potential  
ity for solutes if hydraulic loading were high. Some of  
oils in the basin have soil horizons (B2) with a strong  
ulation of calcium carbonate or calcium sulfate (SCS  
Survey of Castle Rock Area of Colorado). These soils  
have a major impact on phosphorus mobility.

geology of the basin does not indicate the presence of  
e areas for phosphate minerals. The most common  
ate mineral is apatite. It is typically found as  
sory minerals in igneous rocks, in pegmatites, in  
thermal ore veins, in magnetite deposits, in metamor-  
rocks, in bedded marine deposits, as a component of  
bone, shell, and pellets, and in magmatic segregations  
alkalic igneous rocks (Vanders and Kerr, 1967). Apatite  
e found in the rhyolitic rock (Barth, 1962) of the Wall  
ain tuff, but the quantity would be quite small.  
formations during pedogenesis convert apatite to organic  
orus and secondary forms of inorganic phosphorus. The  
lary forms of organic and inorganic phosphorus  
ulate in the finer textured fractions of the soil,  
as the primary phosphorus (apatite) tends to remain in

the sand fractions (Syers and Walker, 1969).

The phosphorus concentration of igneous rocks averages 1100 mg/kg (equivalent to ppm), 700 mg/kg for argillaceous (high clay) rocks, and 593 mg/kg for sandstones (Matthess, 1982), but significant quantities of phosphorus are lost during soil formation by leaching and erosion (Larsen, 1967).

#### Phosphorus Cycle

The Cherry Creek Basin is an open system with respect to phosphorus. The primary basin phosphorus imports would be phosphate fertilizers, and foodstuffs and waste products associated with the human and domestic animal population. The primary basin phosphorus exports would be human waste products, crop removal, and commercial livestock sales. Quantification of phosphorus imports and exports is well beyond the scope of this study. A generalized diagram, from Loehr (1977), of the phosphorus cycle is provided below:

A grassland soil layer active in phosphorus utilization and circulation (the top 80 cm of soil) may have between 6000 to 12000 kg P/ha (5344 to 10688 lb/ac) (Katznelson, 1977). Phosphorus containing compounds can be categorized into two groups--inorganic (orthophosphates and condensed phosphates) and organic phosphates.

Condensed phosphates may occur in nature by excretion from living cells, and release during the decay of dead cells. Condensed phosphates are also added to soil in fertilizer and as detergents. In soil and natural water, condensed phosphate will be hydrolyzed quickly to orthophosphate by microbial action (Larsen, 1967).

Organic phosphorus may comprise up to 90% of the total phosphorus in organic soils and only 7 to 10% of the total P in some desert soils. The availability of organic P varies. Inositol phosphate esters (phytins) are water insoluble and very stable chemically. Phytins originate mainly in plant tissues and in seeds. Nucleic acids contain phosphorus. They are easily transformed to compounds available to plants (Katznelson, 1977).

Estimates of the inorganic and organic content of raw domestic wastewater are 90% inorganic (50% orthophosphate and 40% condensed phosphates) and 10% organic (Snoeyink and Jenkins, 1980). Other estimates suggest that influent water to septic systems contain 65% organic phosphorus (Canter and Knox, 1985).



Better agreement is shown with values of septic tank effluent concentration. Magdoff et al. (1974) found effluent phosphorus (P) concentrations ranged from 15.6 to 24.5 mg/l with a mean of 20.6 mg/l. Otis et al. (1975) found effluent P concentrations ranging from 11.0 to 31.4 mg/l with a median of 12 mg/l. Based on the results of several studies, Canter and Knox (1985) suggest the total effluent P entering the soil averages 15 mg/l.

Anaerobic bacterial activity within the septic tank converts organic and condensed phosphates to soluble orthophosphate (Bouma, 1979). Magdoff et al. (1974) and Otis et al. (1975) found that 85% of septic tank effluent P was orthophosphate. The small amounts of organic P and condensed phosphates will be converted to orthophosphates (Bouma, 1979). The time required for conversion may be influenced by the presence of organic matter and the oxygen content of the soil solution (Robbins and Smith, 1977).

For this study the effluent phosphorus concentration is assumed to be 15 mg/l. Enfield and Bledsoe (1975) presented seven literature values for phosphate concentration in ground and subsurface drainage water from agricultural land and beneath wastewater treatment system. The values ranged from 0.005 to 0.1 mg P/l. Russell (1975) reported that the concentration of P in soil solution usually ranges from 0.03 to 3 mg/l, with a few tenths of a mg/l being most common (Larsen, 1967). Background phosphorus concentrations in the

Cherry Creek Basin as reported in the Clean Lake Study (DRCOG, 1984) are assumed to be within this range. *which?*

### Phosphorus Retention in Soil

One of the primary tasks in developing the phosphorus classification system was to conduct a thorough review of the literature. The purpose of this review was to determine how phosphorus can be retained in the soil and, therefore, not contribute to loadings of Cherry Creek Reservoir. The results of this literature review are presented below.

Soil phosphorus may be moved in three ways (a) by the action of soil microorganisms, (b) with flowing water (mass flow), and (c) by thermal movement along a concentration gradient (diffusion) (Larsen, 1967). Normally the bulk of soil phosphorus is transported by mass flow.

The processes or factors that influence phosphorus movement in soils may be grouped into three general categories--chemical, physical, and biological. It should be noted that the boundaries between categories overlap. Chemical and physical factors influence biological activities, likewise for other combinations of the three.

Chemical Factors: An assumption of most researchers is that the chemical retention of phosphorous, particularly phosphate, is a two stage process. The first stage is a rapid removal process or sorption, and the second stage is

slow mineralization and insolubilization (Tofflemire and Chen, 1977).

At low concentrations ( $< 5 \text{ mg P/l}$ ) the phosphate ions become chemisorbed to iron and aluminum minerals in strongly acid to neutral systems and to calcium minerals in neutral to alkaline systems. At higher concentrations phosphate precipitates form (Bouma, 1979). It has been suggested that in the pH range found in septic tank-drainfield systems (6.5-7.5), hydroxyapatite is the stable calcium phosphate precipitated at relatively high phosphorus concentration such as that found in septic tank effluent ( $15 \text{ mg P/l}$ ). Dicalcium phosphate or octocalcium phosphate are initially formed followed by slow conversion to hydroxyapatite (Lindsay and Moreno, 1960). Variscite and strengite may form in acid soils (Tofflemire and Chen, 1977).

Recent studies indicate that phosphate precipitation is much more complex than solubility data suggest (Whelan, 1986). Many organic substances have been found to decrease the amount of phosphate which reacts with soil. The precipitation and phosphate by aluminum and iron salts over a wide pH is strongly influenced by the addition of many organic and inorganic ions (Chen et al., 1973). When phosphates and organic anions are present together, the decrease in P absorption by an absorbent may arise from the specific absorption of the anion--the result of competition between phosphate and the organic ions for the absorption sites (Reddy et al., 1980).



Some researchers have reported that P sorption capacity of a soil may be independent of previous P treatments (Reneau and Pettry, 1976). Kao and Blanchar (1973) reported that absorption capacities of fertilized and unfertilized silt loam soils were similiar although the soil fertilized for nearly 82 years had almost doubled the total P content. Harter (1968) reported that lake sediments treated to remove P absorption sites, absorbed nearly as much P as untreated sediments.

van Riemsdijk et al. (1979) indicated that more P was sorbed from wastewater than from pure solutions. This may be due to components of the wastewater or different experimental conditions. The most likely explanation was that a combination of aluminum, phosphate, and a cation of wastewater was involved and formed a stable compound (Stuanes, 1984).

Ellis (1973) cited in Bouwer and Chaney (1974) noted regeneration of absorption capacity of P-saturated soil during a 3 month incubation. Regeneration was probably due to crystallization of absorbed phosphate into less soluble compounds and to the production of more iron and aluminum oxides by weathering (Bouwer and Chaney, 1974). Sawhney and Hill (1975) suggested that although the mechanisms for regeneration were not clear, it appeared that drying and wetting at a certain pH created new sites for P sorption on aluminum, iron, or calcium and fresh mineral surfaces.

Stuanes (1984) suggested that repeated additions of a constant concentration appear to give a more realistic estimate of the soil's long term sorption capacity. The repeated addition method had much higher sorption than that resulting from increasing the P concentration. Adsorption isotherms are typically developed using high concentrations of phosphate which changes with time.

Under normal conditions, organic phosphates in soil appear to exist as insoluble ferric and calcium salts, or as absorbates with amorphous and crystalline clays (Halstead and McKercher, 1975). Evans (1985) found that organic P (phytic acid) strongly inhibited P sorption. Inorganic P sorption was reduced to less than 14% of the control when phytic acid in solution exceeded 8 mg/l. This inhibition of inorganic P sorption may accelerate P leaching in coarse soils.

Flooding of soils can result in a reduced (oxygen-deficient) environment. Halford and Patrick (1979) found that reduction usually led to a decrease in P sorption and increased the residual P in solution, except at pH 6.5 where enhanced P sorption was apparently caused by increased adsorption on newly precipitated iron compounds. Sah and Mikkelsen (1986) found that soil flooding and draining, with or without added organic matter, increased the P sorption significantly over unflooded soils. Added organic matter significantly enhanced conditions for P sorption in drained soils--assuming the organic matter was anaerobically decomposed. In well-drained soils, the application of organic matter has been reported to

decrease P sorption (Meek et al., 1979; Reddy et al., 1980).

Hill and Sawhney (1981) noted that anaerobic conditions produced during periods of high water table enhanced the mobility of P. Additional adsorption became less efficient, and some of the P may have desorbed at sites adjacent to preferred flow paths (macropores) and moved on to the groundwater.

Physical Factors: Important physical factors are believed to be water retention time (pore water velocity), unsaturated flow length (depth to groundwater), hydraulic loading rate, phosphorus loading rate, soil mineralogy, soil particle size, and the total soil volume and weight through which the wastewater will pass (Tofflemire and Chen, 1977).

Selim et al. (1975) suggested that an increase in pore water velocity decreased sorption of applied P. Low pore water velocities would encourage solute interactions with soil particle surfaces. Small pores which have a small pore water velocity offer conditions of the longest residence times. The greater the residence (water retention or detention) time the greater is the time allowed for time-dependent (kinetic) sites to react with P (Camargo et al., 1979).

Unsaturated flow length or depth to groundwater have an impact similar to pore water velocity. The more time allowed for particle surface interactions, the more likely adsorption/precipitation reactions may take place. Slow movement

of soil or ground water allows precipitation of soluble phosphate with calcium. The greater the distance, the greater the P removal (Jones and Lee, 1979).

If the hydraulic loading rate or the phosphorus loading rate are high, the probability for phosphorus retention by a given volume of soil is lower. Nagpal (1986) noted that the fraction of added P sorbed at equilibrium ranged between 38% and 87% for gravelly sandy loam and gravelly loamy sand soils, and was influenced by both effluent concentration and hydraulic loading. He found that an increase in effluent hydraulic loading affected the P sorption by soils more than the effluent P concentration.

A differentiation must be made between soil mineralogy and soil particle size (texture). There are clay minerals and clay separates (clay-sized particles). Jones and Lee (1979) reported that the potential of soil to remove phosphate from septic tank effluent is controlled by the mineralogy of the area soils rather than by the soil particle size. O'Hallaran et al. (1985, 1987) found that soil texture (particle-size related) significantly influenced the form and distribution of the various phosphorus fractions in a loamy soil. They indicated that up to 90% of the spatial variability in soil phosphorus could be accounted for by changes in texture. Both soil mineralogy and soil texture are important factors. Clay minerals influence the sorption reactions (adsorption and precipitation) that take place. Clay separates are also involved in sorption reactions and are particularly important

because of the high surface area available for activity. Also, the higher the clay content and fine material content, the higher the water holding capacity and usually the lower the hydraulic conductivity (permeability). Thus, the longer the retention time, the more organic and condensed P can be converted to orthophosphate, and the more likely the orthophosphates will be precipitated (Robbins and Smith, 1977).

Biological Factors: Important biological factors include the microbial alteration of the solubility of inorganic P compounds, the mineralization of organic P compounds by microbes, the immobilization of inorganic P into cellular components (Alexander, 1977), the uptake of P by plants and animals, crop and animal removal, bacterial predation by larger organisms (Cole et al., 1978), and evapotranspiration.

Many organisms can bring insoluble inorganic phosphorus compounds into solution. From 10 to 50% of bacterial isolates taken from soil are capable of solubilizing calcium phosphates, and counts of the solubilizing bacteria may range from log 5 to log 7 per gram of soil. These bacteria are often abundant near root surfaces. The common organisms capable of solubilizing inorganic phosphates are Pseudomonas, Mycobacterium, Micrococcus, Bacillus, Flavobacterium, Penicillium, Sclerotium, Fusarium, and Aspergillus (Alexander, 1977; Higgins and Burns, 1975).

Applying high energy material (soil carbohydrates or organic



matter having a large carbon to phosphorus ratio) to soils stimulates bacterial activity and may solubilize otherwise insoluble soil P compounds and lead to the formation of organic P (Cosgrove, 1967). Manure serves as a good source for organic matter and as an aid in P movement via increased bacterial activity (Meek et al., 1979) and decreased phosphorus sorption capacity (Reddy et al., 1980).

Mineralization of organic phosphorus is related to the quantity of substrate. Soils rich in organic P will be most active. Mineralization proceeds even at sites where inorganic phosphorus is present in large amounts (Alexander, 1977). Mineralization of organic P is a slow process, despite the abundance of appropriate microorganisms (Higgins and Burns, 1975).

Microbial immobilization occurs when large amounts of carbon and nitrogen are available. Microbes are relatively rich in phosphorus--bacterial phosphorus is 1.5-2.5% of dry weight (Higgins and Burns, 1977).

Plant uptake of phosphorus is variable. Crops act as a removable phosphorus sink. This represents 20-25 kg/ha/year (18-22 lb/ac/year) for common grains and straw. About 5 kg/ha/year is left behind in the plant base and roots (Katznelson, 1977). The P concentration in the plants is dependent on the crop, soil, climate, and management factors including the amount of P added to the soil (Ryden and Pratt, 1980).

Crop and animal removal are difficult to determine. A good pasture transfers 30-45 kg P/ha/year from soil through plant to cattle, but a large part is not utilized and returns to the soil in dung. About 50% of the P in fresh dung is soluble and can be utilized by plants. This solubility is reduced as the dung dries (Katznelson, 1977). Grazing accounts for little P removal because grazing cattle and sheep return about 85% of dietary phosphorus to soil (Bouwer and Chaney, 1974). Harvested crops contain only 10% or less of the P added during the season in which the crop was grown, but recoveries as high as 50 to 60% are possible (Russell, 1973).

Bacterial predation may aid in phosphorus mobility in a limited way. Hannapel et al. (1964a and 1964b) found that an increase in the microbial energy source showed an increase in water-soluble phosphate as well as the amount of organic P. The increase of P movement was about 38-fold, with more than 95% of the P moving being organic (Hannapel et al., 1964b). It was suggested that this movement was associated with microbial cells and cellular debris (Hannapel et al., 1964b; Meek et al., 1979). Cole et al. (1978) found that although much inorganic phosphorus was assimilated and retained by bacteria, most was returned to the inorganic phosphorus pool by bacterial grazers--particularly amoebae.

Evapotranspiration can remove large quantities of water from the soil, and in the process enhance the tendency of phos-

phorus to move upward toward the surface (Sharma et al., 1985). The depth of the phosphorus, the water content of the soils, and the type and amount of vegetation would be critical factors influencing the importance of evapotranspiration.

The relative importance of these biological factors to the transport or retention of phosphorus coming from septic tank-leachfield systems is difficult to determine. This difficulty is compounded by the limited research activity in this area.

In summary, several factors appear to favorably affect the retention of soil phosphorus:

1. Intermittent hydraulic loading of effluent.
2. Well-drained, aerobic soils.
3. Limited soil organic phosphorus.
4. Presence of aluminum, calcium, and iron compounds.
5. Low pore water velocity and increased retention time.
6. Long unsaturated flow length.
7. Fine-textured soils with clay minerals present.
8. Limited organic carbon influx.
9. Extensive plant growth to encourage evapotranspiration.

In contrast to the above list, it may be concluded that coarse-textured soils, lack of clay minerals, short unsaturated flow paths, and high pore water velocity appear to unfavorably affect phosphorus retention in soils.



## Soils Map Development - Phosphorus Retention Classes

Tofflemire and Chen (1977) provided a list of factors to consider in evaluating a site for phosphate retention:

- (a) the load of phosphate to be applied in kg P/yr.
- (b) the unit capacity of the soil to rapidly remove phosphate.
- (c) the total soil volume and weight through which the wastewater will pass.
- (d) the increase in removal due to slow mineralization of the rapidly absorbed phosphate.

These factors, addressed in a different format, were the primary factors used to categorize the Cherry Creek Basin soils into three classes based on their potential to retain phosphorus coming from on-site wastewater systems. Because of limited available information, and the limited possibilities of using existing procedures for developing, quantitatively-defined classes, the basin soils were grouped into those soils of "Poor" (low) phosphate retention probability, those of "Intermediate" (moderate) retention probability, and those of "Good" (high) retention probability. (See Appendix F).

The primary agronomic, geologic, and geomorphic resources available on the Cherry Creek Basin soils were Soil Conservation Service Soil Surveys, U.S. Geological Survey surficial geology maps, U.S.G.S. depth to groundwater maps, U.S.G.S. bedrock aquifer maps, and U.S.G.S. topographic maps.

SCS Soil Survey information provided general information on the physical and chemical states of the basin soils. Information was provided on depth to bedrock, soil texture, presence or absence of calcareous soils, presence or absence of coarse-grained layers, soil permeability (hydraulic conductivity), and soil reaction (soil pH).

U.S.G.S. surficial geology maps in conjunction with SCS soil information, provided information regarding soil pedogenesis (formation), bedrock outcrops, and potential soil permeability.

U.S.G.S. depth to groundwater and bedrock aquifer maps provided information about probable unsaturated flow length for various soils in the basin.

U.S.G.S. topographic maps provided information regarding proximity to main drainage channels, potential for soil saturation during spring runoff or following heavy rains, and location of shallow bedrock areas in relation to other soils and drainage channels.

Soils were classified based on distance of travel to primary basin drainage channels, distance of travel in unsaturated soils, the presence or absence of calcareous soils, and the soil texture.

Soils classified as "good" for retention were generally quite

distant from major drainage channels, were generally located where groundwater was thought to be at depths greater than 20 ft. and commonly more than 100 ft., and were generally fine-grained and often calcareous.

Soils classified as "intermediate" were generally non-calcareous, coarse-grained, in areas of shallow bedrock or shallow water table, and possibly near drainage channels.


Soils classified as "poor" were generally in alluvial material or shallow water table regions adjacent to drainage channels.

#### Soil Phosphorus Retention Percentages

In order to estimate the possible or potential loadings to Cherry Creek Reservoir of phosphorus from onsite systems, it is necessary to assign each soil class a phosphorus retention percentage. However, it must be noted that the choice of soil phosphate retention percentages was arbitrary. Insufficient data are available to provide accurate percentages for each soil type. Results of phosphorus retention studies provided in the literature are diverse and site-specific. These literature results influenced the classification of various soils, but little more. In choosing the range of percentages for each soil group, several factors were taken into consideration. Many of these factors were mentioned in the previous sections.

The length of the unsaturated flow path is very important.

Unsaturated flow limits water transport to areas close to particle surfaces where absorption and precipitation reaction take place. Unsaturated flow suggests low volume transport or higher detention time. Higher detention time aids in the adsorption and precipitation reactions mentioned earlier, and it facilitates biological reactions whether microbial or plant related. Few of the field tests summarized in the Appendix C or mentioned in journal articles suggest that phosphorus was transported further than few feet in unsaturated soil or a few 10's of feet in saturated soil. Based on the information available for this study, it is assumed that in a large percentage of the Cherry Creek Basin the soils have long unsaturated flow paths, and as a result, will retain virtually all the phosphorus coming from the septic tank-leachfield systems. The low phosphorus load coming from houses, the intermittent nature of the loading, the semi-arid climate with high evapotranspiration, all indicate that phosphorus has a short length of travel. Until additional data indicate otherwise, it is assumed that in those soils rated as "good" for soil phosphorus retention virtually all phosphorus is retained within a short distance.



Many of the soils in the "intermediate" retention group are clay-dominated soils, often judged calcareous by the SCS. Many of the on-site systems located in these soils are "engineered" systems. These systems often rely on evapotranspiration for liquid removal. Plants may become a phosphorus sink in these areas, and as a result, these systems allow little if any phosphorus to pass to the

groundwater. Some of the soils in the "intermediate" group are shallow soils near drainage channels. These are the "unknowns". Many of these drainage channels carry water only during runoff periods-primarily following major storms. It is difficult to judge whether subsurface flow on the bedrock carries solutes to the nearby streams. Very likely much of the water is transported into fractures in the bedrock--in which case it should become part of the bedrock aquifer systems below. Because of the nature and location of many of the soils in shallow bedrock, county regulations would prevent installation of septic tank- leachfield systems, so phosphorus loading from domestic waste would not be a factor.

The soils grouped as "poor" in phosphorus retention are very difficult to quantify, thus the wide range. These soils are usually in or near drainage channels, and typically consist of alluvial material that may be wet during much of the year. Saturated soils tend to mobilize phosphorus. These soils may have more organic material because of greater plant growth in the area and more animal activity near the streams. The organic matter may facilitate more microbial activity which can alter the typical phosphate absorption/precipitation assumptions. Plant growth (particularly phreatophytes) can act as a phosphorus sink and alter the water balance in the stream area. Many of the soils in this group are located near drainage channels or in the flood plain, so county regulations would preclude housing developments.

The soil categories have ranges or "risk bands" that were



chosen without direct quantitative basis. They are:

Good retention	90 - 100%
Intermediate retention	75 - 89%
Poor retention	55 - 74%

The ranges increase as the likelihood of phosphorus retention decreases because the number of influencing factors and the unknowns associated with them increase.

## ASSESSMENT OF CURRENT AND FUTURE SITUATION

### Introduction

One of the primary functions of Phase 1 is to conduct a preliminary assessment of current and future phosphorus contributions to Cherry Creek Reservoir from onsite systems. The assessment consisted of determining the number of residences within the basin that utilize onsite sewage disposal systems. Through the use of Douglas County Planning Department's computer mapping capabilities, an estimation of the number of residences in each soil type was obtained. These data along with projected phosphorus retention capabilities presented in the previous chapter were utilized to estimate phosphorus loadings from onsite systems.

These estimated contributions were compared to the 450 pound phosphorus allocation that exist for onsite sewage disposal systems. The purpose of this analysis is to determine if there is a need for additional study of onsite systems in the Basin and to make a determination as to whether Tri-County's onsite sewage disposal system regulations should be amended to better address phosphorus removal.

Because of the lack of a detailed soils and geotechnical field investigations and laboratory studies, the estimated phosphorus values presented in the assessment should not be viewed as a precise quantification of phosphorus loading.

Instead, the intent of the assessment is to provide information to guide future activities, such as additional studies on the adoption of interim regulations and BMP's.

#### Current Development

The large lot subdivisions in the Basin served by onsite sewage disposal systems are presented in Table 2 and are shown in Figure 1 of Appendix F.

The existing unit values were obtained by direct house counts in Arapahoe County and from the 1986 Residential Development Monitoring Report (Douglas County Planning Department, 1987) for Douglas County. Table 3 summarizes these data.

Based upon a per capita flow rate of 45 gallons per day (EPA, 1980) and an occupancy rate of 3.25 persons per residence, it is estimated that the total daily wastewater flow generated by onsite systems is approximately 470,000 gallons per day (gpd) which is almost equivalent to the largest point source discharge in the Basin (Denver Southeast Suburban Water and Sanitation District). However, it must be remembered that the contributions from onsite systems are non-point and distributed over the Basin's 246,000 acres. At buildout of currently approved development, total flow from septic systems would be approximately 850,000 gallons per day



Table 2

## Lot Summary Cherry Creek Basin

<u>Subdivision</u>	<u>Units or Lots Approved</u>	<u>Existing Units</u>
1. Algonquin Acres	80	50
2. Allred subdivision	19	15
3. Country Village	40	24
4. Stage Run	51	6
5. Lazy Hills Ranchetts	18	13
6. Cherry Creek East	40	28
7. Arcadian Acres	64	35
8. Kamp Sub		
9. Sierra Vista Estates		
10. Arcadian Heights		
11. Rancheros Felices	194	127
12. Almor Estates		
13. Park Ridge Estates		
14. Honey Suckle Hills		
15. Piney Creek Ranches	106	85
16. Saddle Rock Ranches	78	51
17. Antelope	117	93
18. Arapahoe Meadows	8	6
19. Arapahoe Heights	104	42
20. Chapparal	229	95
21. Travois	52	18
22. Chenango	206	155
23. Kragelund Acres	19	11
Total Arapahoe County	1425	854

Douglas County

<u>Subdivision</u>	<u>Units or Lots</u> <u>Approved</u>	<u>Existing</u> <u>Units</u>
24. Ausfahl	1	0
25. Bartos	2	0
26. Black Forest Est & Ranch	158	112
27. Crestview	64	38
28. Edwards	2	0
29. Forest Hills	58	48
30. Lincoln Properties	4	0
31. Livengood Hills	106	97
32. Lone Pine Acres	4	0
33. NDB	4	1
34. Panacea	1	1
35. Parker East	99	72
36. Parker View Estates	43	19
37. Pine Dale	4	2
38. Pine Palm	3	1
39. Ponderosa East	126	83
40. Redler	3	0
41. Stagecoach Acres	11	6
42. Sunset Ridge	5	0
43. Taylor	2	0
44. Tomahawk Hills	4	3
45. Wallen's	4	0
46. Windy Hills	100	45
47. Butterfield	79	47
48. Cherry Creek Highlands	56	34
49. Dalton	1	0
50. Grandview Estates	256	145
51. Homestead Hills	136	67
52. King Ranch Estates	8	6
53. Lutheran Church	1	0
54. Panorama	11	5
55. Parker Hills Estates	12	6
56. Parker Village	15	11
57. Pine Lane	15	10
58. Pine Valley	51	31
59. Ponderosa Hills	397	290
60. Rodine	1	0
61. Sierra Vista	48	36
62. Smith's	2	0
63. Iravois	56	34
64. Valley Hi	24	13
65. Wilwood	37	0
66. Oak Hills	82	36
67. Surry Ridge	143	140
68. S. Ridge Estate	49	6
69. Bannockburn	185	94
70. Black Kettle Estates	3	0
71. Cottrell's	4	0
72. Dewitt	4	0
73. Flintwood Hills	190	130
74. Fox Hills	101	0
75. Flassburn	1	1
76. Gpant	2	0

77. Hidden Village	175	104
78. Hills at Bayou Gulch	93	23
79. Marshalls	2	1
80. Martin Ridge	1	0
81. McNeish	2	0
82. Random Valley	27	14
83. Singing Hills	18	13
84. Scenic Ridge	4	1
85. Sheffield	4	0
86. Burning Tree Ranch	68	52
87. Castle Oaks	111	0
88. J. K. Nest	1	1
89. Millers Valley	3	0
90. Mity Pines	60	7
91. Oakland Heights	3	2
92. Parker View South	1	0
93. Richlawn Hills	13	6
94. Szymanski	5	0
95. Whispering Pines & North	84	67
96. Beverly Hills	97	47
97. Charter Oaks	42	18
98. Happy Canyon Ranches	17	20
99. The Bluffs	11	8
100. Brigadoon	7	0
101. C & Y	2	0
102. Cleveland	2	0
103. Comanche Pines	23	14
104. Conestoga Pines N & S	20	13
105. Deerfield	274	53
106. Echo Acres	6	5
107. Holmes	2	0
108. Larae	2	0
109. Pine Creek West	14	5
110. Pinewood Knolls	88	20
111. Russellville	159	99
112. Talquesal	4	1
113. Woodhaven	16	10
114. Castlewood	15	5
115. Castlewood North	41	31
116. Pine-Mor	2	0
117. Reed Hollow	3	3
118. Village Pines	15	9
119. Best Butte Ranches	24	1
120. El Dorado Acres	31	4
121. Forest Park Estates	12	4
122. Grimes Ranch	9	5
123. Mesa Grande	59	23
124. Olen	4	0
125. Sandi Acres	4	0
126. Spring Valley West	4	1
Total Douglas County	4461	2360

Table 3  
Build-out of Large Lot Subdivisions  
in the Cherry Creek Basin

County	Approved Lots	Built	Non-Built
Arapahoe	1425	854	571
Douglas	<u>4461</u>	<u>2360</u>	<u>2101</u>
Totals	5782	3214	2568

Developed Area Soils

Figure 1 in Appendix F also presents the distribution of the three soil classifications developed in the Basin, i.e. Low, Intermediate and Good Phosphorus retention soils. To determine the percentages of each of these soil classes that exist in the large lot developments in the Basin, the computer mapping capabilities of the Douglas County Planning Department (DCPD) were utilized. DCPD digitized three soil classes in Figure 1 and entered these data into a computer file. The Arapahoe County developments also shown in Figure 1 were also digitized and filed (Files for Douglas County developments existed prior to this study). The computer was then able to calculate the area of each soil type that exists in each development in each county. The results of this work are presented in Table 4.

Over 75% of the area in existing developments in both Counties is classified as having good phosphorus removal capability. Less than 15% of existing subdivisions is in

the poor classification.

Table 4

Distribution of Phosphorus Retention

Soil Classes \* in Approved Large

Lot Developments in Arapahoe and Douglas Counties

County	Soil Classification	Area, Acres	% of Total
Arapahoe	Poor	700	17
	Intermediate	400	10
	Good	3100	73
Douglas	Poor	2700	12
	Intermediate	2300	10
	Good	17,700	78

\*Phosphorus Retention Soil Classes were developed based upon their ability to retain or remove phosphorus from sewage in onsite sewage disposal systems (see previous chapter). The percentage retained or removed which will not contribute to phosphorus loadings is estimated as follows:

Low	55% - 74%
Intermediate	75% - 89%
Good	90% - 100%

Estimated Wastewater Flows

Once the distribution of each Soil Classification was determined, the next step in estimating a phosphorus loading was to determine the approximate amount of wastewater that was being treated through onsite systems in each soil type. To arrive at estimated flows for each soil class, it was assumed that the number of residences in each type was proportionate to the area for that soil class. However, this assumption was not applied to the Poor classification because field investigation verified that construction has not routinely taken place in these areas. Areas classified

as Poor are routinely low lying and associated with floodplains and/or drainages. A combination of available mapping and field investigation were used to estimate the number of units in the Poor classification. Table 5 presents the estimated wastewater flows from onsite sewage disposal systems that are being treated by each Soil Classification.

From this analysis it appears that over 85% of the wastewater from onsite systems is being treated by soils in the Good classification and approximately 2% in the soils classified as Poor.

Table 5  
Estimated Wastewater Flows From Onsite System  
In Each Soil Classification

County	Soil Classification	# of Residential Units	Wastewater Flow,mgd*
Arapahoe	Poor	15	.0022
	Intermediate	92	.0135
	Good	747	.1092
Douglas	Poor	60	.0088
	Intermediate	265	.0388
	Good	2033	.2976

\*Million gallons per day. Based upon 3.25 persons per unit and 45 gallons per capita per day.

### Current Phosphorus Loadings

Utilizing the estimated phosphorus removal capability of each soil type and the projected wastewater flow being treated by onsite systems in each classification, the amount of phosphorus in pounds per year that reaches groundwater in the Basin can be estimated. The results of this analysis are presented in Table 6.

Table 6  
Estimated Phosphorus Reaching  
Groundwater in Cherry Creek Basin

County	Soil Classification	Wastewater Flow mgd	Unretained* Phosphorus, mg/l	Phosphorus Reaching Groundwater, pounds/yr
Arapahoe	Poor	.0002	3.90 - 6.75	26 - 45
	Intermediate	.0135	1.65 - 3.75	68 - 154
	Good	.1092	0.00 - 1.50	0 - 498
Douglas	Poor	.0088	3.90 - 6.75	104 - 180
	Intermediate	.0388	1.65 - 3.75	195 - 442
	Good	.2976	0.00 - 1.50	0 - 1358
Total				393 - 2677

\* Assume Septic Tank Effluent Phosphorus Concentration = 15 mg/l

Unretained Phosphorus Concentrations are estimated as follows:

Unretained Phosphorus = (15 mg/l) (100% - Phosphorus Retained)

Phosphorus Retained Values are: Low = 55% to 74%  
Intermediate = 75% to 89%  
High = 90% to 100%

Utilizing the upper level of projected phosphorus removal capability for each soil type, it is estimated that onsite systems are currently contributing approximately 400 pounds per year of phosphorus. With the lower level of projected removal or retention, onsite systems would be contributing approximately 2700 pounds per year to area groundwater.

The 400 - 2700 pound per year range presented above is an estimate of phosphorus contributions to groundwater and is not intended to reflect phosphorus loadings to the reservoir from onsite systems. A significant percentage of the wastewater treated by onsite sewage disposal systems is believed to end up as recharge to groundwater in the Dawson Formation. The actual amounts of groundwater in the Dawson Aquifer that discharge to Cherry Creek or the Cherry Creek alluvium are not well documented in the literature. However, the USGS estimated that groundwater flow through the Cherry Creek alluvium to the Reservoir was 104 acre-feet/year (DRCOG, 1984). Onsite systems at that time generated approximately 500 acre feet/year of wastewater. By comparing the estimated groundwater flows to the Reservoir and current volume of wastewater produced by onsite systems, it appears that only a limited amount of water from this source reaches the Reservoir. However, time of travel in the aquifer and other numerous hydrologic factors would have a bearing on how these data should be interpreted.



The fate of wastewater treated by onsite systems that recharge the Dawson Formation was discussed with Robert Longenbaugh, Assistant State Engineer at the Division of Water Resources. Mr. Longenbaugh pointed out that the interaction between the bedrock aquifer and the Cherry Creek alluvium is very transient, i.e. conditions are not static. He reported that significant declines in water levels in the bedrock aquifers have been noted in some areas. Continuation of these declines could result in a change in hydraulic gradient whereby outflow from the Dawson to the Cherry Creek alluvium could reverse and the alluvium would discharge to the Dawson. If this were to occur, phosphorus contributions to the Cherry Creek alluvium from onsite systems via groundwater would also decline.

Further documentation that a significant percentage of phosphorus from onsite systems is not reaching the Reservoir comes from an analysis of data in Clean Lakes Study (DRCOG, 1984) performed by DRCOG as a part of the preparation of the Cherry Creek Basin Master Plan (DRCOG, 1985). This analysis assumed that all phosphorus in groundwater that reached the Reservoir in the 1983 monitoring effort was from septic systems. The necessary septic system effluent concentration to achieve the total groundwater loading to the Reservoir was then calculated to be 0.058 mg/l utilizing a per capita flow rate of 75 gpd. This level of treatment would result in an annual load of 138 pounds per year at the verified current level of large lot development in the Basin.

### Future Phosphorus Loadings

Based upon the findings of this Phase 1 study, it is recommended that DRCOG's average estimated septic system concentration of 0.058 mg/l continue to be utilized as a basis for projecting loadings from onsite sewage disposal systems.

The Master Plan (DRCOG, 1985) projected that the large lot subdivision population in the Basin would increase to 19,500 people in 1990; 36,800 by 2000; and 52,600 by 2010. Applying the 0.058 mg/l average concentration, the annual phosphorus loading from onsite systems would be 260 pounds in 1990; 490 pounds in 2000; and 700 pounds in 2010.

## SUMMARY, CONCLUSIONS & RECOMMENDATIONS

### Summary

Presented below is a summary of the major findings of this study:

1. The literature was reviewed relative to the physical, chemical and biological factors involved in a soils capability to retain or remove phosphorus from wastewater. This information in conjunction with available soils and geologic data was utilized to develop a Soil Phosphorus Retention Classification System for the Basin. Soils were classified as "Good", "Intermediate" and "Poor" in terms of their phosphorus retention capabilities.
2. Because of the number of site specific variables that determine the quantity of phosphorus removed in a soil at a given location, it is difficult to assign precise phosphorus removal percentages to the developed soil classifications. Detailed soils/geotechnical field investigations and laboratory studies would be required to develop quantitative data. However, retention percentage ranges were assigned to the soil classes as follows:

<u>Classification</u>	<u>% Retained</u>
Poor	55-74
Intermediate	75-89
Good	90-100

These ranges are utilized to obtain an estimation of how well area soils are removing phosphorus from onsite systems.

3. There are approximately 5782 approved lots in Arapahoe and Douglas Counties which are proposed to utilize onsite sewage disposal systems. Approximately 3200 of these lots have been built on to date. The total daily wastewater flow generated by the septic systems serving these residences is estimated to be 470,000 gpd. Buildout of the approved developments will result in an ultimate flow from onsite systems of 850,000 gpd.
4. Over 75% of the area in approved developments has soil classified as having "Good" phosphorus removal capability. Less than 15% is in the "Poor" classification.
5. Construction has not routinely taken place in areas classified as "Poor". These areas are normally low lying and associated with floodplains and/or drainages.

6. It is estimated that over 85% of the wastewater from onsite systems is being treated by soils in the "Good" classification and only 2% by the soils classified as "Poor".
7. Based upon the projected phosphorus removal ranges of each soil class and estimated wastewater flows being treated in each classification, the amount of phosphorus contributed to groundwater from onsite systems in the Basin was estimated to be between 400 and 2700 pounds per year. Actual values are believed to be at or below the lower limit of 400 pounds.
8. Phosphorus contribution to groundwater may not be as critical as how much groundwater in the Basin actually interacts with Cherry Creek and the Cherry Creek alluvium and therefore places a phosphorus loading on the Reservoir. It is believed that a significant percentage of the wastewater treated by onsite systems may never interact with the Reservoir. The bases for this statement are:
  - a. Groundwater flow to Cherry Creek Reservoir was estimated in the Clean Lakes Study to be 104 acre-feet/year. At that same time all onsite systems in the Basin generated a flow of approximately 500 acre-feet/year.

- b. Continued decline in water levels in the Dawson Aquifer may result in a change in hydraulic gradient whereby outflow from the Dawson to the Cherry Creek alluvium could reverse and the alluvium would discharge to the Dawson. A consequence of such an occurrence could be a decline in phosphorus contributions to the Cherry Creek alluvium from onsite systems recharging the Dawson.
- c. Groundwater monitoring and groundwater reservoir inflow data in the Clean Lakes Study were utilized by CDH to estimate a 1982 phosphorus loading from groundwater of 130 pounds. A 99.6% onsite sewage disposal removal efficiency would have been necessary to achieve this annual poundage if it were assumed that all phosphorus in groundwater came from onsite systems.

### Conclusions

Based upon the findings presented above, it is concluded that onsite sewage disposal systems are a significant source of phosphorus in the Cherry Creek Basin. However, the soils and geology of the Basin in conjunction with existing Tri-County Regulations (see Appendix E for Regulation Overview) have resulted in systems overall achieving a high level of

phosphorus removal.

If significant portions of wastewater from onsite systems interact with the reservoir, the phosphorus loading from this source would be much greater than the currently allocated 450 pounds/year. For example, if all existing systems achieved 97% phosphorus removal and if all wastewater from systems interacted with the reservoir, annual loading from this source would be over 600 pounds. However, DRCOG's evaluation of data in the Clean Lakes Study support the conclusion that significant amounts of wastewater from onsite systems do not reach the reservoir (DRCOG, 1985). Current loads to the reservoir are believed to be less than the allocated 450 pounds per year.

#### Recommendations

Until such time as additional information becomes available, it is recommended that DRCOG's average estimated septic system effluent concentration of 0.058 mg/l continue to be utilized as a basis for projecting phosphorus loadings from onsite sewage disposal systems. *to the Reservoir?*

Based upon this study it is believed that there is a need for some interim changes to how onsite sewage disposal systems are regulated in the Basin. The need for change is not based upon a belief that the phosphorus allocation is being or soon will be exceeded. Instead, this study has identified through its literature search, Best Management Practices (BMP) that



can minimize phosphorus contributions from onsite systems. It is believed to be in the best interest of the Basin to implement these BMP's prior to even nearing the 450 pounds allocation. Thus it is recommended that the following BMP's be implemented in the Basin.

1. All onsite systems should be excluded from designated 100 year floodplains. Although there is a general policy to not accept proposed leachfields in floodplains, present regulations do not preclude installation in these areas. This practice will greatly restrict installation of systems in areas designed as "Poor" for phosphorus retention in this study.
2. New large lot subdivisions being processed through the County Subdivision review processes should be required to address the suitability of onsite sewage disposal in relation to phosphorus removal. Tri-County should work with Douglas & Arapahoe County Planning Departments to develop submittal criteria for proposed projects to follow.
3. The hydraulic loading of onsite systems in coarse soils with rapid percolation rates should be reduced to provide a larger surface area for phosphorus removal and to increase the depth of unsaturated flow.

4. Tri-County Health Department should develop a program to encourage the use of low phosphate laundry detergents in homes utilizing onsite systems in the Basin.

BMP's 1 and 3 would be accomplished through an amendment to Tri-County's onsite sewage disposal regulations. BMP #2 would require a new provision in County subdivision or zoning regulations.

In addition there are numerous BMP's or design criteria presented below that may improve an onsite system's ability to remove or retain phosphorus on a long term basis.

1. Require that onsite systems be dosed to provide a more equal distribution of wastewater which may enhance phosphorus removal in some soil types. (Dosing involves applying wastewater to leachfields at a high rate period discharge to spread wastewater over the entire leachfield).
2. Increase the separation distance from the bottom of leachfields to maximum seasonal water tables to increase the depth of unsaturated flow and enhance phosphorus removal. (Currently 4 feet of separation is required).

3. Increase setback requirements from drainage ways and dry gulches (currently 50 feet) since these areas are normally associated with soils having "Poor" phosphorus retention capabilities.
4. Require soils tests to determine minerology, i.e. presence or absence of aluminum, calcium or iron compounds. Develop design criteria for loading and/or depth of soil to ensure adequate phosphorus removal based upon the results of these tests.
5. Place maximum system depth at a level whereby aerobic conditions will prevail and evapotranspiration will be encouraged.
6. Require alternating leachfields to enhance the regenerative absorptive capacity of leachfields.
7. Preclude the use of conventional systems in fine textured soils.
8. Require groundwater quality monitoring of large commercial systems.

It is not recommended that these additional BMP's be implemented until there is a documented need for additional action in the Basin or until further study documents that the BMP is worthwhile. This recommendation is made because the conclusions reached in this Phase 1 Study are educated guesses

based solely on a literature review.

#### Further Study

It is recommended that sufficient further study be conducted to verify numerous assumptions that were made in preparing this report. The proposed Phase II Study in Appendix D presents a scope of work which is believed to generally provide the needed information. However, it is recommended that Task 2.3 be de-emphasized relative to work associated with developing and calibrating a predictive long-term phosphorus removal model. Instead, field and laboratory testing should emphasize providing data relative to what proposed BMP's listed in Table 7 or other BMP's are most worthwhile implementing.

Appendix A  
Soils of Arapahoe  
and Douglas Counties

## APPENDIX A SOILS OF ARAPAHOE AND DOUGLAS COUNTY

NOTE: Following each soil name, placed in parenthesis, are the SCS map symbol, depth to bedrock in inches, and range of pH (if known), and "+" or "-" based on general probability of soil to retain phosphorus. Factors that influenced that classification are included.

Blakeland loamy sand (BoE,BIE; >60; 6.1-7.8; -)

- rapid permeability; coarse loamy sand to sand; sand at depth

Blakeland-Orsa association (Bo; >60; 6.1-7.8; -)

- as above, possibly more gravelly

Bresser loamy sand (BrB,BrD; >60;6.1.8; -)

- loamy sand to sand; moist below 4 ft in areas; moderate permeability

Bresser sandy loam (BsB; >60; 6.4-7.5; +)

- clay loam sublayer; spots of lime accumulation

Bresser-Stapleton sandy loam (BuD,BuE; >60; 6.4-7.5; +)

- clay content; more grave in Stapleton areas

Bresser-Truckton sandy loam (BvC,BvE,BtE; >60; 6.1-7.8; +)

- sandy clay loam at depth

Bresser-Truckton soils (BwD2,BuD2; >60; 6.1-7.8; +)

- sandy clay loam in some areas, gravelly sandy loam in other areas

Brussett loam (BvB,BvD; >60; 7.0-8.5; +)

- moderate permeability; strongly alkaline; silt loam; lime at 20-40"

Buick-Satanta loams (BwD; >60; 6.6-7.8; +)

- very strongly calcareous; sandy clay loam to clay loam

Coni rocky loam (Co6; 10-20; 5.6-7.8; -)

- bedrock less than 20"

Crowfoot-Tomah sandy loams (CrE; >60; 5.6-7.8; +)

- clay loam of moderate permeability; turning to gravelly sandy loam and coarse sand at depth

Cruckton sandy loam (CsD; >60; 6.1-7.8; +)

- sandy loam with moderately rapid permeability; sandy loam to gravelly sandy loam

Cruckton-Peyton sandy loam (CtE; >60; 6.1-7.8; +)

- similar to above, although Peyton areas have greater clay content

Englewood clay loam (En; >60; 6.6-9.0; +)

- very slow permeability; calcium carbonate concretions to a depth of 60"

Fondis clay loam (FoB, FoD; >60; 7.5-9.0; +)

- very strongly calcareous clay loam with dense clay layers

Fondis-Colby silt loams (FoC; >60; 7.5-9.0; +)

- strongly calcareous; Kutch has clay shale

Gravelly land (Gr; >60; 6.6-8.4; +)

- gravel at depth; bedrock outcrops

Hilly gravelly land (Hg; 2-40; NA: -)

- shallow soil, bedrock less than 20"; cobbly clay loam in places

Jarre-Brussett (Jb; >60; 6.1-7.8; -)

- gravel at 20-60"

Kettle loamy sand (KeE; >60; 5.1-6.5; \_)

- moderately rapid permeability; coarse sandy loam or loamy sand at depth

Kettle-Falcon complex (KfF; ?60; 5.1-6.5; \_)

- as above, gravelly sandy loam

Kippen loamy sand (KnE; >60; 5.6-7.3; -)

- rapid permeability; gravelly, gravel below 40"

Kippen and Pring soils (PpD2; >60; 5.6-7.3; -)

- gravelly sandy loam with rapid permeability



Kutch sandy loam (KtE; 20-40; 6.1-8.4; +)

- slow permeability; fine-textured calcareous material from clay shale

Kutch clay loam (KuD, KuE; 20-40; 6.1-8.4; +)

- as above with higher clay content

Kutch-Newlin-Stapleton complex (KwF; 20-40; 6.1-8.4; +)

- as above, although Newlin-Stapleton areas more permeable

Litie silty clay loam (LcD; 20-40; 7.5-8.5; +)

- clay loam; strongly calcareous

Loamy alluvial land (Lo, Lu, Lv, Lw; >60; 6.1-8.4; -)

- subject to flooding every year; noncalcareous, although some areas have calcareous clay loam; some areas remain wet or are flooded during storms

Manzanola clay loam (Ma; >40; 7.3-9.0; +)

- strongly calcareous, but shale bedrock at 72"

Newlin gravelly sandy loam (NeE; >60; 6.1-7.8; -)

- gravelly sand to depths of 60" or more

Newlin-Satanta complex (NsE; >60; 6.1-7.8 -)

- as above, although Satanta soils are clay loam

Nunn loam (NIB; >60; 7.5-8.5; +)

- loam to clay loam; calcareous at depth

Nunn-Bresser-Ascalon complex (NrB; >60; 7.5-8.5; +)

- as above, although Bresser-Ascalon more permeable

Peyton sandy loam (PeB, PeD; >60; 5.6-7.3; +)

- moderate permeability; clay loam layers

Peyton sandy loam, wet (PfC; >60; 5.6-7.3; -)

- as above, although water table often at 36", and soil cemented at 40"

Peyton-Pring-Crowfoot sandy loam (PpE, PrE2; >60; 5.6-7.3; +)

- clay loam areas present, but more gravelly than Peyton sandy loam

Pring and Kippen gravelly sandy loams (PvE; >40; 5.6-7.3; -)

- moderatelyapid permeability with fine gravel at dept

Renohill loam, reddish variant (ReE; 20-40; 7.5-8.5; +)

- slow permeability; calcareous clay material

Renohill-Buick loams (RhD, RhE, RnE; 20-30; 7.3-9.0; +)

- as above, weathered from clay shale; calcareous; shallow bedrock

Renohill-Little clay loams (RID; 20-30; 7.5-8.5; +)

- calcareous clay material; slow permeability

Renohill-Little-Thedalund complex (RtE; 23-30; 7.5-8.5; +)

- as above, although Thedalund areas have fragmented shale and sandstone

Renohill-Manzanola clay loams (RnE; 20-40; 7.3-9.0; +)

- weathered from calcareous clay shale

Renohill sandy loam, reddish (RoE; 20-40; 7.3-9.0; +)

- red clay loam; slow permeability; non-calcareous

Sampson loam (Sa; >60; 6.1-8.4; +)

- slow permeability; strongly calcareous clay loam

Samsil-Little stoney clays (SIF; 6-14; 8-8.5; +)

- calcareous clay shale; shallow bedrock; slow permeability

Samsil-Renohill clay loams (SrE; 6-14; 8-8.5; +)

- calcareous clay shale; shallow bedrock; slow permeability

Sandy alluvial land (Sd, Se, Su; >60; 6.1-8.4; -)

- sandy material along stream channels; non-calcareous; subject to flooding; gravelly in areas; moist below 12" in some areas (Se)

Satanta loam (Sn; >60; 6.6-8.4; +)

- strongly calcareous clay loam; moderate permeability

Stapleton loamy sand (SsE; >60; 6.1-7.8; -)

- moderately rapid permeability gravel at depth

Stapleton sandy loam (SWE; 20-40; 6.0-7.0; -)

- rapid to moderate permeability; sandstone bedrock at 20-40"

Stapleton-Bresser association (St; >60; 6.1-7.8; -)

- moderately rapid permeability in sandy material; shale or sandstone at 40" depth in Bresser areas

Stony rough or steep land (Su,Sv,Sw; 10-40; NA; -)

- rhyolite, shale, or sandstone bedrock at 10-40"

Terrace escarpments (Tc,NA, NA, -)

- subject to erosion into drainages

Truckton sandy loam (TrD; >60; 6.1-7.8; +)

- moderately rapid permeability; sandy loam to 60"; clay films; borderline soil

Truckton loamy sand (TrC,TrE; >60; 7.0-8.0; -)

- non-calcareous; rapid permeability

Wet alluvial land (Wt; >60; 6.5-7.5; -)

- yearly flooding; water table at 36", next to streams

Appendix B  
Regional Analysis  
of Soil Map

## APPENDIX B - REGIONAL ANALYSIS OF SOIL MAP

The map of the Cherry Creek Basin showing phosphorus retention likelihood has three categories of retention--Poor (Low), intermediate (moderate), and Good (High). "Poor" areas are largely confined to drainage channels. "Intermediate" areas are in one of two groups--(a) those soils which are not in major stream channels yet have specific physical or chemical characteristics which make phosphorus transport more likely, and (b.) those soils adjacent to Cherry Creek, between the reservoir and Franktown, which are part of the immediate flood plain. Based on information provided by U.S.G.S. topographic and depth to groundwater maps, these areas are thought to be closely connected to Cherry Creek in a hydrological sense--i.e. they may have shallow water tables, they may be wet during runoff periods, and the actual distance for solute transport to the stream channel may be short. "Good" areas contain soils that are thought to retain phosphorus better than others, or the depth the groundwater or distance to drainage channels is great.

The following information is provided to indicate the reason for "Intermediate" classification of those areas away from the Cherry Creek channel. Starting on the eastern side of the Cherry Creek Reservoir and going clockwise around the basin--

1. Area near the start of Smokey Hill Road and further east in Sections 15 and 27--Truckton loamy sand, non-calcareous with rapid permeability.
2. Remaining areas in Arapahoe County, east of Cherry Creek--Stapleton sandy loam, rapid permeability, shallow bedrock.
3. All areas east of Cherry Creek from the Arapahoe County line to the area near Hilltop--Stapleton-Bresser association, moderately rapid permeability in sandy material, shallow bedrock in some areas.
4. Area just west of Hilltop in section 8--Stapleton-Bresser association and Stapleton loamy sand, rapid to moderate permeability with shallow bedrock. The same soils are present in parts of section 18 and 13 to the west.
5. In sections 23 and 24 along Bayou Gulch--Blakeland loamy sand and Blakeland-Orsa association, rapid permeability, coarse loamy sand to sand, gravelly in areas, sand at depth.
6. In sections 20 and 21 to the east--areas of loamy alluvial or sandy alluvial land, subject to flooding, and occasionally wet below 12". An are of Stapleton loamy sand is located in the center of section 21.

7. In sections 35 and 36 northeast of Franktown and section 33 on the Elbert County line--Stapleton loamy sand and Stapleton-Breser association soils, described in 3 and 4 above.

8. Along Reed Hollow, southeast of Franktown--Blakeland loamy sand, described in 5 above.

9. Near Russellville in sections 17, 18, 13--Stony steep land and Newlin gravelly sand in sections 18 and 13, Loamy or sandy alluvial land in section 17.

10. In section 33 and 28 at the upper end of Russellville Gulch--Hilly gravelly land with shallow bedrock.

11. Along Cherry Creek from Old Castlewood Dam to the junction of the East and West branches of Cherry Creek--sandy alluvial land and Coni rocky loam with bedrock less than 20".

12. In the area near the junction of Haskel Creek and West Cherry Creek--sandy alluvial land, Coni rocky loam and Kippen loamy sand, rapid permeability, gravelly, and gravel below 40".

13. Along East Cherry Creek from section 21 south to section 9--an area of shallow water table and Jarre-Brusset soil, with gravel at 20-60".

14. Further south along East Cherry Creek--more Jarre-Brusset and sandy alluvial material in sections 16 and 21.

15. East of East Cherry Creek in section 28--Kippen and Pring soils, Kettle-Falcon complex, and Pring and Kippen gravelly sandy loam, gravelly sandy loams with rapid permeability.

16. West of East Cherry Creek--just north of the El Paso County line, Jarre-Brusset gravelly soil and Pring and Kippen gravelly sandy loam.

18. Along West Cherry Creek in the area near Cherry Valley School--large areas with shallow water table, Jarre-Brusset gravelly soils, Pring and Kippen gravelly sandy loam, and Kippen loamy sand.

19. At the junction of Crowfoot Creek and West Cherry Creek--an area of shallow ground water, Kippen loamy sand and Pring and Kippen gravelly sandy loam.

20. Along Crowfoot Creek--Kettle-Falcon gravelly sandy loam.

21. Along side channels of West Cherry Creek just north of the Bucks Mountain--Kettle-Falcon gravelly sandy loam and Kippen sandy loam.

22. West Cherry Creek from Bucks Mountain to the El Paso County line--Kippen and Pring gravelly sandy loam, Kippen loamy sands, Pring and Kippen gravelly sandy loam, and Jarre-Brusset gravelly soil.

23. Along Haskell Creek--large areas of shallow ground water, Kippen and Pring gravelly sandy loam and Kippen loamy sand.

24. Between Nenrick Butte and Lincoln Mountain--Jarre-Brusset gravelly soils, Kippen loamy sand, and sandy alluvial land.

25. At the upper reaches of Haskell Creek and Antelope Creek--Kippen loamy sand, Kettle loamy sand, and wet Peyton sandy loam.

26. At the upper reaches of Upper Lake Gulch and Lake Gulch--Jarre-Brusset gravelly soils and stony steep land with shallow soils (near Corner Mountain).

27. East of Hunt Mountain in section 24--stony steep land and Coni rocky loam with shallow bedrock.

28. Near the junction of Upper Lake Gulch and Lake Gulch--Kippen loamy sand and wet Peyton sandy loam.

29. West of the gulch junction and in the upper reaches of WillowCreek--stony steep land and Coni rocky loam.

30. In areas south and west of Castlewood Canyon recreation area--stony steep land, Coni rocky loam, Kettle-Falcon gravelly sandy loam.

31. In Mitchel Gulch--Coni rocky loam with shallow bedrock.

32. Along the road west of Franktown--stony rough land, Coni rocky loam, and Newlin gravelly sandy loam.

33. In section 28 west of Pikes Peak Grange--Newlin gravelly sandy loam.

34. Along McMurdo Gulch--hilly gravelly land with shallow bedrock, Coni rocky loam with shallow bedrock, and stony rough land.

35. Along Scott Gulch--hilly gravelly land and Newlin gravelly sandy loam.

36. In all areas north to the Arapahoe County line--Newlin gravelly sand in the lower parts of drainages, and hilly gravelly land, stony rough land, or Coni rocky loam in the upper reaches. Coni rocky loam evident near Happy Canyon and southwest of Beverly Hills.



37. Near the Arapahoe County Airport--an are of gravelly land.

Appendix C  
Field and Laboratory Studies  
of Phosphate Retention

$$\frac{2700 \text{ kg}}{\text{ha}} \times \frac{1000 \text{ g/kg}}{10000 \text{ m}^2/\text{ha}} = 2700 \times \frac{1}{10} = 270 \text{ g/m}^2/\text{yr}$$

## APPENDIX C - FIELD AND LABORATORY STUDIES OF PHOSPHATE RETENTION

Numerous scientific investigations, both in the field and in the laboratory have been conducted over the years. The investigations were typically oriented in one of two directions--toward optimizing phosphorus fertilizer application rates, or toward testing the feasibility of land application of wastewater.

Most of the investigations had a common format--phosphorus concentrations were varied, the hydraulic loading rates were varied, the length of applications varied, and the physico-chemical states of the soil varied. Likewise, the results varied.

Larson (1960) cited in Bouwer and Chaney (1974) found that 75% of the 2700 kg P/ha/yr applied with wastewater was removed after 9 m of movement through coarse soil. A New York State Department of Health (1972) study cited in Jones and Lee (1977) reported that for several sites with medium to coarse sands and gravels, with groundwater at various levels below the surface (2.4 m to 9 m depth), P retention was greater in unsaturated soil. Accounting for dilution in the saturated zone, P removal was 1.7 to 2.1%/m in saturated soils and 2.5 to 9.0%/m in unsaturated soils. P reduction was 34 to 52% in the first 0.46 m of unsaturated soil. In silty sand P reduction was 11.9 to 26.3%/m. Dudley and Stephenson (1973), also cited in Jones and Lee (1977), reported 99.1 to 99.9% removal 4.6 m downgradient in outwash sand with a water table at 3.4 m depth. Hill (1972) reported comparisons in P retention between acidic and alkaline soils. The two soils were a fine sand loam with a pH of 5 to 5.5 and a loam with a pH of 7.2 to 8.0. With input P concentration of 8 mg/l, 100% removal occurred in the A horizon of the acidic fine sand loam and 85% removal occurred in the A horizon of the loam during the first 12 months of the study. Peaslee and Philipps (1981) reported results on sandy and acid organic soils of leaching P down the soil profile.

Sawhney and Starr (1977) summarized a few investigations on different application rates. Moderate rates (5 cm/wk) for several years resulted in little movement below 15 cm soil. Higher rates (230 cm/wk) to sandy soils for several years produced 5 mg P/l in subsurface waters.

Long term studies have provided variable results. Larson et al. (1974) cited in Kardos and Hook (1976) reported that after 6 years of irrigation with poultry waste of 15 mg P/l, 98% removal occurred in the first 90 cm depth. With an annual irrigation of 508 cm, only 0.4% of the 3500 kg P applied reached the groundwater. Kao and Blancher (1973) showed that soil treated for 82 years with phosphate fertilizers had a higher total P content to a depth of 137 cm than the soil that received no phosphate fertilizers. Bouwer et al. (1974) reported an investigation of P-removal efficiency at a rapid infiltration basin of sandy and gravelly material. during the 5 year operation 48000 kg/ha (43000 lb/ac) of phosphate-P was applied. The P removal was about 50% after 30 ft. (9.1 m) of underground

travel and 90% removal after 300 ft. (100 m). the sands and gravels contained little or no iron and aluminum oxides, so P removal was thought to be caused by calcium phosphate and ammonium magnesium phosphate precipitation. Kardos and Hook (1976) reported a 9 year study of silt loam and clay loam soils. Loading was 5 cm/week of 7 mg P/l orthophosphate. In the clay loam soil at 120 cm, P concentration remained at background levels--0.05 mg P/l. In the sandy loam the P concentration increased slightly, but after 9 years 96% of added P was retained in 120 cm soil. They suggested that the soil held 78% of the P, and 22% was harvested in hay. Sommers et al. (1979) found that a majority of P applied to soils during 11-12 years of wastewater application remained in the upper 30 cm of clay loamy soil, while noticeable amounts of P leached to 30-60 cm depth in sandy loam soil. Latterell et al. (1982) reported on silt loam soils with a water table at 140 cm and gravel at 60 cm. With 5 years of loading at 237 cm/year and an initial concentration of effluent P of approximately 7 mg P/l, 88% of P retention occurred within 60 cm. Nagpal (1985) reported a column study of gravelly silt loam subjected to a daily dose of 66 cm secondary effluent (5.2 mg P/l). After 2.7 years of effluent loading, about 60-90% of added P was being removed by the 60 cm soil columns.

Changes in application periods reduced phosphate mobility. Greenberg and McGaughey (1955) found that percolation through 3 m of fine sandy loam was required to reduce phosphorus (P) concentrations below 1 mg/l after 2 years of continuous flooding with secondary sewage effluent. When the soil was flooded intermittently on a 1 week flooding-1 week drying cycle, 0.3 m of soil was needed. The hydraulic loading rate was 15 cm/day. John (1974) reported that phosphate removal by a 20 cm column of calcareous meadow soil was 97% initially, but decreased to 81% after 77 days of intermittent flooding. The hydraulic loading rate was 7 cm/day. Logan and McLean (1973), using sandy, silty, and clay loam soils in laboratory columns, found that constant head loading resulted in greater P movement out of the surface layer and greater accumulation in the leachate than with intermittent loading. With intermittent loading, P concentration fell off rapidly at the 8 cm depth. With constant loading, P concentration was almost constant with depth. Input phosphorus concentrations varied from 50 to 1250 kg P/ha. The hydraulic loading rates varied from 1.3 to 5 cm/day. Beek et al. (1977a) reported a study of sewage water (33 mg P/l) applied once a month in 200 mm applications. They found no significant difference in soil layers below 70 to 80 cm of flooded and non-flooded soil. Lance (1977) subjected calcareous loamy sand columns to 9 days flooding/5 days drying cycles. He indicated that 90% of the P was removed from sewage water containing 12 mg/l P. He suggested that after the initial adsorption was saturated, 75% to 80% of applied P could be removed by maintaining loading rates below 15 cm/day.

The cause for the variation in retention between constant and intermittent loading was not determined. Sawhney and Hill (1975) suggested that possible wetting and drying might create new surfaces for P sorption.

Most of the previously mentioned studies, as well as most of those found in the literature but not presented here, report limited phosphorus mobility in soil. There are numerous exceptions--some of which are mentioned here. Levine et al. (1980) reported on a 30 year application of unchlorinated primary effluent to soils ranging in texture from gravelly sandy loam to coarse sand and gravel. Only 30% of the total applied P could be accounted for within the upper 30 cm of the soil profile. Hortenstine (1976) found greater than 1.2 mg P/l at 60 cm in a fine sand after only a few months of wastewater application--a fourfold increase over pretreatment levels at the site. Iskandar and Syers (1980) observed 7.3 mg P/l, 10 times higher than a nearby untreated site, in soil water collected at 80 cm. The site was loamy sand subjected to 4 years wastewater application.

Nagpal (1985) summarized the findings of Sawhney (1977) and Tofflemire and Chen (1977) and P retention in soil columns subjected to near continuous leaching under both saturated and unsaturated conditions: (a.) all added P was sorbed by the soil initially, (b.) breakthrough of P occurred after an amount of P equivalent to that sorbed by the soil after 200 hours of reaction time in an isotherm test was sorbed by the columns (Sawhney, 1977), and (c.) after breakthrough, leachate P concentration increased steadily with time and reached the same value as the effluent (Tofflemire and Chen, 1977).

As indicated in the studies above, variability in phosphorus retention can be expected. The results of each investigation are unique to the conditions of the experiment. As a result, these investigations have limited value to this study in a quantitative sense. In laboratory column studies, the soil structure is destroyed during the process of grinding and sieving the soil. Phosphorus activity in these soils is not the same as that in the unaltered soil. In field investigations, cost and time constraints limit sampling. Spatial variability of soil phosphate retention in the field is not usually investigated. Few investigations reported the in-site chemical state of the soils under consideration.

Appendix D  
Scope of Work

EXHIBIT A

SCOPE OF WORK  
CHERRY CREEK BASIN

An Evaluation of  
Phosphorus Contributions to Cherry Creek Reservoir  
From Onsite Sewage Disposal Systems

January, 1987

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## INTRODUCTION

The Cherry Creek Basin Water Quality Management Plan was adopted in 1985. The plan contains a control program to ensure that the reservoir standard for phosphorus adopted by the Water Quality Control Commission will be maintained. An integral part of this control program is the adoption of Best Management practices (BMP's) to assist in reducing the contribution of non-point sources of phosphorus to Cherry Creek Reservoir. Only two non-structural BMP's are proposed, i.e., erosion control regulations and septic tank regulations.

In relation to septic tank regulations, the Nonpoint Control section of the plan states:

"Septic Systems provide another source of phosphorus which is presently unregulated with respect to phosphorus. If the basin must regulate point and non-point phosphorus, it follows that septic systems should also meet certain phosphorus performance standards. Arapahoe and Douglas counties, in cooperation with Tri-County Health, shall develop septic system criteria for meeting phosphorus standards."

Thus, the ultimate outcome of this study will be revision to Tri-County Health Department's onsite sewage disposal regulations which will set forth phosphorus performance criteria for onsite systems as is mandated by the Plan.

A four phase study is proposed to accomplish the regulatory revisions outlined in the Master Plan. The study is proposed to occur over the next two years. The estimated costs of the effort are \$50,000 to \$60,000. This level of funding is believed to be essential to provide the factual and scientific basis for making a regulatory revision which may have major economic implications to parties constructing onsite sewage disposal systems in the Cherry Creek Basin.

For example, a regulatory revision which increased the average cost of a system by \$1,000 would result in an estimated overall cost increase ignoring inflation, of \$10,000,000 by the year 2010. (These figures are derived from a Master Plan estimate that an additional 30,000 persons will be served by onsite systems by the year 2010). With this magnitude of financial implication it is imperative that there be a strong basis for the regulatory revision.

The remainder of this scope of work outlines the four phases of the study.

PHASE I: Data Collection and Preliminary Assessment of Current and Future Situation

1.1 The first step in this study will be to make a

preliminary evaluation of the effectiveness of soils in the Cherry Creek Basin for removing phosphorus. Existing soils and geologic data will be utilized in this evaluation. Possible sources of data which may be utilized in this effort include:

- a. Soil Conservation Service Mapping
- b. Applicable Colorado Geologic Survey Mapping and publications.
- c. Applicable U. S. Geologic Survey Mapping and publications.
- d. Tri-County Health Department soil profile and percolation data from permit applications.
- e. Available well logs.

The existing data will provide generalized information on soil mineralogy, soil types, soil permeability, and unsaturated soil depths, all of which play important roles in a soils ability to remove phosphorus. Based upon the above factors and how they contribute to phosphorus removal, the Basin soils will be assigned a phosphorus removal classification, i.e., high, moderate, low.

1.2 Based upon the available literature and work done in Summit County, project a probable range of phosphorus removal that could be expected for each soil classification.

1.3 With the assistance of Arapahoe and Douglas County Planning Departments, determine the approximate number of residences and establishments that currently exist in each soil classification.

1.4 Utilizing the results of Tasks 1.2 and 1.3, estimate the current level of phosphorus loading from onsite sewage disposal systems.

1.5 Incorporating land use information from Douglas and Arapahoe County Planning Departments and the large lot population projections in the Master Plan, estimate future phosphorus loading from onsite sewage disposal systems.

1.6 Prepare a draft report to the Basin Authority which presents the results of Phase I.

1.7 Amend the Scope of Work for Phase II, III and IV as required to reflect the results of Phase I. Primary importance should be given to prioritizing soils for Phase II field and laboratory analysis.

1.8 In the event interim regulations for an onsite system are determined to be appropriate, all or portions of the draft report may be developed as a final report by Tri-

County and the Cherry Creek Basin Authority to support the adoption of such interim regulations.

## PHASE II: Soils Analysis and Model Development

The final scope of work for Phase II will be determined following the completion of Phase I. At that time a request for proposals will be prepared for work to be performed by an outside consultant(s). On a preliminary basis, the major tasks proposed under Phase II are outlined below:

2.1 Analyze the physical and chemical characteristics of priority basin soils through the use of field and laboratory testing. The goal of this task will be to provide data which can be utilized to correlate a soils' physical properties with its phosphate removal ability.

Soils analysis may include:

<u>Physical</u>	<u>Chemical</u>
Field Profile Logs	Total Phosphorus
Field Percolation Tests	Total Calcium
Soil Classification	Total Iron
Grain Size Distribution	Total Aluminum
Uniformity Coefficients	Exchangeable Aluminum
Moisture Content	Soluble Fluoride
Vertical & Horizontal permeability	Lime Estimate
Atterberg Limits	Plant Available
	P, K, Zn, Fe, Mn, Cu
	Nitrate
	Organic Matter
	Conductivity

2.2 Determine the phosphorus removal capabilities of area soils through the use of absorption isotherm tests and soil column tests. Sufficient work should be done in these areas to determine phosphorus removal efficiency under dynamic conditions so that test results can be used to calibrate a Onsite Sewage Phosphorus Impact Model. The removal results should be compared to physical and chemical soil properties.

2.3 Utilizing the results of Tasks 2.1 and 2.2 develop and calibrate a model to predict a long-term phosphorus removal from onsite sewage disposal systems in the Basin. If possible the results of this task should mesh with the phosphorus removal soil classifications developed in task 1.1.

2.4 Utilizing the Results of Task 2.3, estimate current and future phosphorus loading from onsite sewage disposal systems.

2.5 Prepare and submit a Phase II report to the Counties, Basin Authority and CDH for review and approval.

## PHASE III: Best Management Practices and Design Criteria

3.1 The purpose of Phase III will be to utilize the results of Phase I and II to develop BMP's and specific septic system design criteria which will accomplish the goals of the Master Plan, i.e., 95% initial phosphorus removal and 80% long-term removal. Specific items to be considered and evaluated in this work include:

a. System sizing on a hydraulic versus phosphorus limited basis.

b. Soil characteristics and conditions under which system should and should not be allowed.

c. System location in relation to direction of groundwater flow.

d. Conditions under which groundwater monitoring should be required.

e. Maximum system size.

f. Dosing requirements.

g. Criteria under which old systems should be replaced.

3.2 Prepare a Phase III report for review and approval of the Counties, Basin Authority and CDH.

#### PHASE IV: Amend Regulations

4.1 In order to put the BMP's and design criteria developed in Phase II into practice it will be necessary to amend Tri-County's Regulation I-85. The procedures required to accomplish this task are outlined below:

a. Prepare preliminary draft of the proposed rules and regulations.

b. Submit draft to Colorado Department of Health; Adams, Arapahoe and Douglas Counties Basin Authority; system contractors and other effected parties for review and comment.

c. Schedule workshops on the revisions where appropriate.

d. Revise draft based on comments.

e. Schedule and conduct Public Hearing.

f. Make changes as required based upon Public Hearing.

g. Adoption of final regulation by Tri-County Board of Health.

h. Final Approval of Adopted Regulation by Colo-  
rado Department of Health.

Appendix E  
Administration of Onsite  
Sewage Disposal in  
the Basin

## APPENDIX E

### Administration of Onsite Sewage Disposal System in the Basin)

Onsite sewage disposal systems are regulated in the Basin by Tri-County Health Department. Tri-County's Regulation I-85 sets forth minimum standards for the location, construction, performance, installation, alteration and use of individual sewage disposal systems. These regulations were adopted pursuant to CRS 25-10-104 and the 1984 Guidelines on Individual Sewage Disposal Systems developed by the Colorado Department of Health (CDH). The regulations apply to all forms of sewage disposal for which the design flow is less than 2,000 gpd. Systems with design flows greater than 2,000 gpd category are not covered by the Regulation if they are connected to a sewage treatment works. Systems in the greater than 2,000 gpd capacity can be installed under the provisions of the regulation if the ultimate form of disposal is through an absorption system (leachfield), and if site approval is obtained through CDH.

Properly sited, designed, installed and maintained onsite sewage disposal systems can provide an effective form of wastewater treatment. Presented below are the basic components of Tri-County's program to assure that onsite sewage disposal meet the requirements of the state statute and CDH guidelines.

1. Conventional septic-tank leachfield systems are only allowed in areas where onsite testing by a registered professional engineer indicates there is suitable soil. Suitable soil means a soil which will effectively filter effluent by removal of organisms and suspended solids before the effluent reaches any highly permeable earth such as joints in bedrock, gravels, or very course soils and which meets percolation test requirements and has a vertical thickness of at least four feet.
2. Extensive requirements in terms of required separation distances between various septic system components (tank, leachfield, sewage lines, etc.), and wells, lakes, water courses, ditches streams and dry gulches.
3. An onsite review of each application is conducted by Tri-County prior to the issuance of a permit to verify soil suitability and site conditions.
4. All septic systems are installed by contractors licensed by Tri-County. An examination and/or training session are licensing requirements.
5. All systems are inspected and approved by the Department prior to backfilling.

6. Conventional systems are not allowed to be installed in areas where the following conditions exist:
  - a. The percolation rate is slower than 60 minutes per inch.
  - b. The percolation rate is faster than 5 minutes per inch.
  - c. The maximum seasonal level or the groundwater table is less than four feet below the proposed system.
  - d. Bedrock exists less than four feet below the pattern of the proposed system.

Special engineered systems, such as evapotranspiration systems, may be allowed in the above areas. Provided the systems designed by a registered professional engineer and approved by Tri-County.

7. Owners of systems are required to inspect their septic tank a minimum of every two years and to pump the tank a minimum of every four years.
8. Septic tank pumping is only conducted by pumpers licensed by Tri-County. Septage can only be disposed of at locations and by such methods as approved by the Department. Presently the only approved method in the Tri-County area is to haul pumpings to an approved wastewater treatment plant that will accept the waste.
9. In accordance with State law, Arapahoe and Douglas Counties will not issue a building permit for a structure to be serviced by an onsite system until a permit for the sewage disposal system is issued by Tri-County. Likewise certificate of occupancy are withheld until the system has been inspected and approved.
10. It is Department Policy that onsite systems not be allowed in new developments with a density greater than one dwelling unit per acre provided a public water system is available. If onsite wells are proposed the density decreases to one unit per 2.5 acres.

Based upon the literature review conducted in this Phase 1 Study, it is believed that Tri-County's existing regulations are effective in assuring that onsite systems provide a high level of phosphorus removal. In particular, the requirements for a minimum of four feet of suitable soil beneath leachfields; setbacks from water courses and dry gulches; conservative loading rates; and density of development are thought to enhance phosphorus removals.



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