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Volume IV
Ecological Risk Assessment to Support the Phase I and Phase II Environmental Site Assessment of the United States Sugar Corporation Properties

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LIST OF ACRONYMS

ADaPT	Automated Data Processing Tool
BMP	Best Management Practice
CD	Compact disc
CERP	Comprehensive Everglades Restoration Plan
COIs	Contaminants of Interest
COPECs	Contaminants of Potential Ecological Concern
CSM	Conceptual Site Model
District	South Florida Water Management District
DON	Department of the Navy
EAA	Everglades Agricultural Area
EPCs	Exposure Point Concentrations
ERA	Ecological Risk Assessment
ESA	Environmental Site Assessment
FDEP	Florida Department of Environmental Protection
GEO-EAS	Geostatistical Environment Assessment Software
GIS	Geographical Information System
LOAELs	Lowest-Observed-Adverse-Effects-Levels
NOAELs	No-Observed-Adverse-Effects-Levels
OCPs	Organochlorine Pesticides
OPPs	Organo-Phosphorous Pesticides
PEC	Probably Effect Concentration
PEC-Q	PEC-Quotient
PSI	Professional Services, Inc.
RBCs	Risk-based Concentrations
SLERA	Screening-level Ecological Risk Assessment
SQAGs	Sediment Quality Assessment Guidelines
STAs	Storm Water Treatment Areas
TEC	Threshold Effect Concentration
TOC	Total Organic Carbon
TRVs	Toxicity Reference Values
UCL	Upper Confidence Limit
USEPA	United States Environmental Protection Agency
USFWS	US Fish and Wildlife Service
USSC	United States Sugar Corporation
WRPs	Water Resource Projects

1.0 INTRODUCTION

This document is Volume IV of the Phase I/II Environmental Site Assessment (ESA) that is being conducted by the South Florida Water Management District (District) in conjunction with its potential acquisition of more than 180,000 acres of land from United States Sugar Corporation (USSC)(Figure 1.0-1).

Before acquiring or using lands for development, the District is undertaking a broadly-scoped due diligence evaluation of the assets being negotiated as part of the purchase agreement. NewFields has been contracted by Professional Services Inc. (PSI), at the request of the District, to perform an Ecological Risk Assessment (ERA) on the agricultural lands as part of the District's due diligence evaluation. The primary goal of the land purchase would be to provide lands for building Water Resource Projects (WRPs) such as storm water treatment areas (STAs) and reservoirs.

The large majority of the lands being considered for acquisition by the District are active agricultural parcels currently being used for sugarcane, citrus, and vegetable production by USSC. Building WRPs on USSC lands would result in flooding these properties, the soils of which are known to contain agricultural chemicals including fertilizers, pesticides, and herbicides which could be toxic to aquatic-dependent wildlife. The District is evaluating the potential suitability of the land for conversion to the aquatic and semi-aquatic habitats characteristic of District WRPs.

A wide range of chemicals are used in the production of sugarcane and citrus. These agrochemicals have historically been and continue to be applied to the land potentially being acquired by the District. Of particular interest are legacy agrochemicals, such as organochlorine pesticides (OCPs), which were historically applied to portions of the lands being contemplated in the purchase. Use of most of these chemicals was banned by the US Government in the early 1970s due to adverse ecological impacts on non-target species such as raptors and aquatic-feeding birds. While the agrochemicals currently being applied to the land have been deemed to be safe by the United States Environmental Protection Agency (USEPA) and are legal for use in sugarcane and citrus farming, the conversion from terrestrial agricultural uses into aquatic and semi-aquatic habitats could be problematic due to the potential for residual concentrations of the agrochemicals to cause unacceptable effects to future aquatic communities or wildlife, including threatened or endangered species.

The Phase I/II ESA is intended to provide due diligence to support purchasing decisions that the District must make regarding the USSC property in the near future. The primary goal of this ERA is to help the District determine which USSC lands could cause unacceptable ecological risks if converted into a WRP in the future and to identify areas where corrective actions or other risk management options may be required to address them

The ERA was conducted using the ERA Protocol that was developed by the District, US Fish and Wildlife Service (USFWS), and the Florida Department of Environmental Protection (FDEP). The Protocol was developed specifically for use in District property transactions and includes methods to assist District and regulatory agency personnel in assessing risk from agricultural chemicals to future wetland and aquatic communities that would develop if WRPs were built. The Protocol includes two main phases; a screening-level ERA (SLERA) and an expanded risk assessment. The SLERA is intended to identify chemicals that are present at concentrations that exceed conservative (i.e., environmentally protective) benchmarks. In many situations, the District can make purchasing decisions and scope corrective actions using the SLERA results.

The expanded risk assessment includes data collection and laboratory analyses that are used when more information about bioavailability or toxicity is needed to make decisions and is usually conducted only after SLERA results have been reviewed by the District and USFWS. The analyses in the expanded risk assessment may include direct testing of soil toxicity to sediment dwelling organisms, measures of bioaccumulation of agrochemicals in soil into plant and animal tissues or other tests identified to address site-specific ecological risk concerns. These tests can take many weeks to design and complete, and usually include some consultation with USFWS.

Project-specific expanded risk assessment testing could not be conducted for this ERA because WRP locations and configurations were not known before the Phase I/II ESA. The District did, however, attempt to anticipate some data needs and conducted a limited set of toxicity and bioaccumulation tests based on experience with assessing risks in sugarcane and citrus agriculture at other sites, and preliminary laboratory reports from chemical analyses conducted for the Phase II ESA process. Soils for this testing were collected from locations thought to be representative of the land-use types and associated potential agricultural chemical composition in the USSC. But the testing is not a comprehensive representation of all areas of the USSC properties due to the unusually large scale of the property and the short timeframe available for the ESA process and purchasing negotiations.

The District will use the results of this risk assessment to help make initial decisions regarding the purchase of the USSC lands based on this level of risk assessment. Depending upon siting of WRPs, final design, regulatory approval and permitting of the WRPs may require additional data collection, laboratory testing, and risk analysis associated with project-specific data needs.

1.1 Site Description

The ERA is designed to focus on the large agricultural tracts being contemplated for purchase by the District. These tracts consist of approximately 187,000 acres of land, more than 220 square miles. The lands are divided into a number of large tracts and consist of more than 140,000 acres of sugarcane fields and 40,000 acres of citrus groves (Figure 1.1-1).

The property is subdivided into a number of smaller areas for management by USSC. For clarity, the USSC land designations will be used to describe subsections of the property. The sugarcane lands are divided into four major areas (Areas 1 through 4) as shown on Figure 1.1-2. Area 1 is located to the west of Lake Okeechobee between the towns of Moore Haven and Clewiston. Area 2 includes areas to the south of Lake Okeechobee from Clewiston east to South Bay. Area 3 extends to the east of the lake from South Bay to Pahokee and Area 4 is located east of the lake from Pahokee north toward Port Mayaca. The approximately 40,000 acres of citrus groves are subdivided into three areas, Dunwoody, Devil's Garden and Southern Division. Southern Division is the largest citrus parcel and represents the southern boundary of the project (Figure 1.1-2).

Each of these areas contains a large number of individual agricultural fields. Fields are broken down into approximately 80-acre parcels and are numbered based on their location with a four-digit number followed by a two letter field designation (sugarcane) or a three-digit number followed by a lettered field designation (citrus). The field designations provided by USSC were used in all investigations and assessments to describe field locations.

The site includes a number of soil types including multiple mucks and sands. General soil types found on the properties are shown in Figure 1.1-3, and are discussed in detail in Volume II of the ESA. The bulk of the property is comprised of the highly organic muck soils located to the south and east of Lake Okeechobee. The majority of the sugarcane fields lie within the muck soil type, but sugarcane is also grown on sandy soils to the west of the lake. Citrus is mainly grown on sandy soils. Vegetables and row crops have been grown, and are currently grown on the properties, especially in Area 2 south of Clewiston.

Current and historical crop types affect the potential herbicides and pesticides present in the soils. For example, areas formerly planted in vegetables and row crops tend to have higher concentrations of persistent OCPs such as DDT, many of which have been banned since the 1970s. The soils in the sugarcane fields tend to contain predominately modern herbicides, and soils in citrus areas are expected to contain more copper due to fungicides applied to orchards. Soil chemistry has also been affected by fertilizers, apparently leading to increased concentrations of metals including arsenic, barium, and copper. Many of the parcels have mixed chemical profiles indicative of the multiple crop types that have been planted through the years.

A complete description of the property and all associated assets is provided in the ESA (Volume II).

1.2 Ecological Risk Assessment Scope and Objectives

The overall ESA is designed to collect data and provide information regarding potential environmental contamination throughout agricultural areas of the entire site as well as potential point sources of contamination including railroad rights-of-way, equipment storage areas, agricultural canals, etc. While these areas are all important components of the overall environmental assessment, they are less important in terms of the assessment of ecological risk than the large tracts of agricultural land being considered by the District for purchase. As a result, only the agricultural tracts of the property are included in the scope of this document. All industrial areas, point source areas, railroads, canals and other non-agricultural tracts are discussed in detail in the ESA but are not discussed further in the ERA.

The ERA includes approximately 141,000 acres of sugarcane fields, 40,000 acres of citrus groves, and approximately 5,000 acres of row crops that make up the vast majority of the overall 187,000-acre property. WRPs are not expected to occupy all of the lands offered by USSC. However, the locations and configurations of the WRPs are not currently known. Therefore, the analysis was conducted for all of the USSC agricultural lands, assuming that any of the properties could be included in a WRP.

As noted above, the ERA was conducted using the Protocol established by agreement between the USFWS, FDEP, and the District. The specific goals of this ERA are as follows:

1) Provide a conservative determination of the contaminants of potential ecological concern (COPECs) present in the agricultural areas of the property;

2) Identify receptors potentially at risk from elevated COPEC concentrations in agricultural soils;

3) Utilize basic procedures in the Protocol together with data from toxicity, bioaccumulation and pore water tests collected for this project or other applicable data to characterize the risks; and

4) Categorize USSC properties based on relative ecological risk levels and potential need for corrective actions to make properties suitable for WRPs.

The large scale of the USSC properties poses some unique problems to the ESA in general, and the ERA in particular. The ERA portion of the ESA is further complicated by the fact that current conditions bear no resemblance to the future conditions under WRPs, and the footprints and configurations of the projects are currently not known. Thus, the ESA and ERA are intended, in part, to help the District determine whether WRPs are feasible within the properties offered and if so, where such projects can be located.

In some portion of the agricultural areas, agrochemicals are present at concentrations that could potentially cause risk to future inhabitants of WRPs constructed in those areas. These areas must be identified to provide District decision makers with adequate information regarding the suitability of the property for use in future WRPs and help to provide an estimate of the scope and cost of corrective actions that may be required to render the property suitable for conversion from agricultural to aquatic land use. To facilitate the purchase decision process, an overall goal of the assessment process was to categorize properties into one of three categories:

> **Category 1:** Moderate or intensive corrective actions ARE NOT NECESSARY for WRPs with acceptable levels of ecological risk to aquatic life and aquatic-feeding wildlife.
>
> **Category 2:** Moderate or intensive corrective actions MAY BE NECESSARY for WRPs with acceptable levels of ecological risk to aquatic life and aquatic-feeding wildlife.
>
> **Category 3:** Moderate or intensive corrective actions ARE REQUIRED for WRPs with acceptable levels of ecological risk to aquatic life and aquatic-feeding wildlife.

Assignment of lands into the three categories was accomplished by using the ecological risk-based benchmarks discussed in the Protocol in conjunction with the limited expanded risk assessment testing conducted in parallel with the SLERA. Approximately 50% of the agricultural areas of the site fall within Category 1 indicating that corrective actions or extensive additional risk-based studies would not be required if WRPs were conducted in those areas. And additional 30% of the agricultural areas fall within Category 3 indicating that chemical concentrations in those areas are elevated to a point where intensive corrective actions are likely to be necessary if a WRP is to be constructed in that area. Additional risk-based studies may have some benefit in those areas and should be considered on a case-by-case basis, but they are not likely to eliminate the need for a substantial portion of the corrective actions necessary. The final 20% of the agricultural areas fall into Category 2 which indicates that some corrective actions may be necessary in these areas but their scope and extent is uncertain. Additional risk-based studies could be very beneficial in these areas. The details associated with the categorization are provided in Sections 2 through 7 of this document.

1.3 Document Organization

This document is organized into eight sections. A conceptual site model (CSM) that includes a complete discussion of contaminant sources, pathways and receptors is provided in Section 2. The types of data available for use in the ERA are provided in Section 3. Section 3 presents sample types, sample numbers, analytical methods used and summary statistics. Section 4 includes a discussion of the screening-level benchmarks available for the completion of the SLERA that is presented in Section 5. Section 6 provides the expanded ERA where results of the toxicity, bioaccumulation and pore water tests are provided along with a more detailed assessment of potential risks that form the basis of the conclusions of the assessment that are provided in Section 7. References are provided in Section 8 and all data used in the assessment, as well as all other supporting information, are provided in the appendices.

2.0 CONCEPTUAL SITE MODEL AND ERA APPROACH

This section summarizes the CSM and the overall rationale and approach for the ERA. The ERA was conducted using methods consistent with the Protocol, modified somewhat to account for the large scale of the properties being assessed.

2.1 Conceptual Site Model

As it applies to ERAs for chemicals, the CSM describes the general aspects of the site that could lead to contact between the chemicals in the environment and the animal and plant species that are the ecological receptors of concern at the site. A preliminary CSM is developed prior to the investigation to guide selection of the types of sampling and analysis needed to assess ecotoxicological risks. Many ERAs are conducted to assess exposure and risk to receptors under current conditions. In these cases, samples of environmental media (soil, sediment, water) and biota are collected and analyzed for chemical concentrations, and the resulting data are used as a measure of exposure.

However, the ERAs performed for CERP properties are being conducted for conditions that do not yet exist since they are currently terrestrial agricultural properties that would be flooded for construction of WRPs. Flooding changes the potential for ecological exposure because many contaminants are more mobile and have greater potential to bioaccumulate in aquatic systems than in terrestrial systems. In addition, many of the receptors of concern are aquatic-feeding wildlife which would be attracted to the newly flooded parcels if an aquatic prey base becomes established. If agricultural chemicals are present at concentrations that exceed protective levels, corrective actions may be necessary during construction to reduce risk to ecological receptors that may occupy the site after flooding.

The fundamental tenant of the ERA process is that in order for risk to occur, a completed exposure pathway must be present. An exposure pathway consists of three primary points. First, a source of the contaminant must be present. In this case, the primary source of contaminants is present as agrochemicals currently found in the soils throughout the property. This source differs from the classic source discussed in ERA guidance (USEPA 1992, 1997 and 1998) where risks are typically assessed due to a release of contaminant. However, because of the fundamental change in land use being contemplated following the creation of WRPs and the large scale of those projects, the regional and sometimes localized concentrations of current and legacy agrochemicals must be considered as the primary and dominant source of contaminants in this prospective ERA.

The second point necessary for an exposure pathway to be complete is the presence of a receptor. The change in land use from agricultural fields to aquatic habitats will cause a dramatic ecosystem shift. That shift will likely create large-scale habitat for aquatic and semi-aquatic receptors. Upon creation of a new aquatic habitat, development of a functioning aquatic community is expected. The community will form beginning with the base of the food web where an aquatic benthic community is expected to develop essentially in parallel with an aquatic vegetation community.

Depending on the depth of the water and type of WRP, fish, amphibian and reptile communities are also expected to develop once the habitat and food web base develop to an extent required for the support of these mid-trophic levels. If the mid-level communities develop, higher trophic level species are also expected to begin to inhabit the new ecosystems. These species are expected to include predatory fish, mammals and aquatic-feeding birds.

One of the benefits of a WRP is not only to provide clean water, but also to provide habitat for aquatic species. As a result, the receptors required for a completed exposure pathway are expected, in time, to be present in future WRPs at the site.

The Protocol clearly defines the type of receptors that must be considered in the ERA. First, the benthic invertebrates that will form a significant base of the aquatic food web are evaluated as the receptor group representative of the aquatic community in the ERA. Effects to this group of receptors could impair the ecological function of the future aquatic community.

Second, the Protocol indicates that upper trophic-level receptors should also be included as representative receptors. Some agrochemicals, particularly legacy organochlorine pesticides that are no longer in use but are still present in the soils, can biomagnify within an aquatic food web. Biomagnification is the process by which a chemical can be found in greater concentrations within tissues of receptors higher in the food web than in the source. As such, the Protocol indicates that the following list of species should be included in all District ERAs for lands to be converted from agricultural land use into aquatic WRPs:

- bald eagle (*Haliaeetus leucocephalus*);
- white pelican (*Pelecanus erythrorhynchos*);
- snail kite (*Rostrhamus sociabilis*);
- osprey (*Pandion haliaetus*);
- clapper rail (*Rallus longirostris*);
- tri-colored heron (*Egretta tricolor*);
- little blue heron (*Egretta caerulea*);
- great blue heron (*Ardea herodias*);
- mottled duck (*Anas fulvigula*); and

- wood stork (*Mycteria americana*).

These species represent those which may be maximally exposed to bioaccumulative agrochemicals. There has been a general agreement with USFWS that bird species should be the focus because they are expected to be more sensitive than mammal species to many of the chemicals, and potentially more exposed due to their feeding habits. In addition, most of the species shown above are considered “Trust Species” by USFWS because they have special status either as federally threatened or endangered species, or are protected under the federal Migratory Bird Treaty Act.

Finally, a pathway from the contaminant source to the receptors must be present in order to complete the exposure pathway. In its current setting, the exposure pathway to aquatic receptors is not present. However, following completion of WRPs, flooding of the soils and the subsequent development of an aquatic ecosystem is expected to complete the exposure pathway. Chemicals present in soils will be contacted by benthic macroinvertebrates through direct contact with sediments and chemicals dissolved in interstitial pore water where they will enter the food web (Figure 2.1-1). Additionally, movement of sediment organisms will disturb the sediments which can release chemicals into the overlying surface water through a process termed bioturbation. As a result, residual agrochemicals currently present in soils can enter the food chain through exposure by species at the base of the food chain or can be released into surface water completing the exposure pathway from the soil/sediment to the receptors of concern in this ERA. Figure 2.2-2 presents a graphical representation of the CSM.

2.2 Ecological Risk Assessment Protocol

The Protocol was developed by the District and USFWS (SFWMD and USFWS 2008) and provides guidance for the conduct of the Phase 1 ESA as well as determining the need for a Phase 2 ESA. If a Phase 2 ESA is deemed necessary, the Protocol provides comprehensive guidance for the environmental sampling of point source areas, agricultural fields and canals within the subject property. The goal of the Protocol is, therefore, to provide a consistent and scientifically defensible assessment of the sometimes large tracts of land purchased by the District. The ESA includes an ERA of the large agricultural areas of each property. The Protocol was not, however, developed with the goal of assessing a tract of land as large as the USSC agricultural tracts (187,000 acres). As such, several modifications were made to the Protocol in consultation with USFWS, FDEP and the District for this project.

Agricultural field sampling under the Protocol is conducted by collecting composite samples over a constant area. Based on the standard Protocol, assessed properties are divided into 50-acre subareas for sampling. A total of 10 sub-samples are collected from within each 50-acre area and are composited to represent an average concentration of contaminants of interest (COIs) within the surface soils (0 – 6 in.) in that area. At very large properties, the target spatial coverage of composite samples is 50% of the total number of 50-acre areas, or grids, within the project. Both the 50-acre composite sample and the 50% target sampling coverage were modified based on discussions with USFWS, FDEP and the District for this project.

The layout of the designated fields on the USSC property provides existing blocks of fields approximately 80-acres in size. Fields are further subdivided into areas approximately 40-acres in size for cultivation purposes. Therefore, rather than creating an artificial 50-acre grid for sampling purposes, the 40-acre fields were adopted as the default composite sample areas. Additionally, obtaining the target 50% coverage of the entire project area was not feasible within the timeframe of the due diligence evaluation. As a substitute, the entire project footprint was stratified into current and former land use types. Areas where the greatest potential for historical pesticide use was the greatest were sampled at a higher density than those where historical pesticide use was expected to be lower. This decision to alter the target sample density was once again made in consultation with the USFWS, FDEP and the District.

Areas of the site that have been shown and are expected to have been cultivated exclusively as sugarcane were targeted for 20% sample coverage because, based on professional judgment and knowledge of typical practices in sugarcane agriculture, agrochemical use is low compared with other types of agriculture. Within the sugarcane fields, a subset of fields were known to have been or were suspected to have been used in vegetable row crop farming at some point in the past. Since row cropping typically requires a considerably heavier use of agrochemicals than sugarcane, these fields were targeted at 50% sample coverage. Finally, the areas of the site utilized as citrus groves were also targeted at 50% sample coverage.

The Protocol also prescribes the use of ‘super-grids’ on very large agricultural properties. These are groupings of a number of adjacent composite sampling areas that are grouped and each super-grid is sampled at the target sampling frequency. This approach is used to increase the uniformity of sample coverage over the entire site and to ensure that samples are collected from all areas of the site.

The super-grid approach was utilized on the USSC property, but was modified somewhat due to field conditions. Because the entire area to be sampled is part of an active sugarcane farm, sugarcane was being cultivated during the Phase 2 sampling, and the sugarcane on some fields was too tall to allow for non-destructive sampling. The super-grid approach was modified slightly by selecting grids to be sampled in each super-grid based on the height of the sugarcane rather than randomly. An attempt was made in several areas to sample tall cane from the edges of the field based on USFWS recommendations, but health and safety concerns limited that approach to just a few fields.

The Phase 2 investigation provided a large dataset for the ERA. The first step of the ERA is the completion of a SLERA. The SLERA is intended to identify COPECs and provide screening-level conclusions regarding the potential for risk to the ecological receptors at the site. The conclusions of the SLERA indicate which COPECs are likely to show a low potential for elevated risk and those that may require further evaluation either through the collection of additional data for use in an expanded ERA or through remediation.

The SLERA is conducted for two general sets of ecological receptors and the screening values are used to identify areas that may require further attention for each receptor. As discussed in the previous section, the SLERA is focused on the assessment of risks to a future aquatic community that may develop following construction of a WRP and risk to aquatic-feeding wildlife.

The Protocol indicates that in cases where clear decisions regarding the potential for risk cannot be reached or where remediation to remove potential risks based on screening-level results is impractical, further testing and completion of an expanded ERA will be necessary in order to refine our understanding of the hazards to federal trust resources associated with contaminants on the site. Given the size of the project and the limited time frame available for the completion of the due diligence evaluation, a series of tests were conducted in consultation with the USFWS to provide a limited set of data typically collected in an expanded ERA before the completion of the SLERA. These decisions were based on professional judgment and experience in conducting SLERAs in both sugarcane and citrus agricultural areas of south Florida. These tests are discussed in more detail in Section 5.

3.0 DATA AVAILABLE FOR USE IN THE ERA

As part of the Phase II ESA investigation, a large number of samples were collected in support of the ERA. Samples were collected following the requirements of the Protocol and were intended to provide as robust and complete database for the estimation of potential ecological risks for the property as possible in the due diligence evaluation. A number of different sample types were collected to aid in the determination of the potential severity and extent of future ecological risk, these included:

- 40-acre composite surface soil samples;
- 5-acre discrete surface soil samples;
- Bulk bioassay samples; and
- False negative samples.

The sampling techniques, intended use of each sample type, analytical methods used and numbers of samples for each sample type are presented in the following sections.

3.1 40-Acre Composite Surface Soil Samples

The large majority of the agricultural tracts were sampled using a composite sampling technique designed to provide an estimate of the average chemical concentrations present in the surface soils.

As discussed in Section 2.2, composite soil samples were collected from a large number of 40-acre fields in both the sugarcane fields and citrus groves across the site. Each composite sample consisted of a total of eight sub-samples collected from within the 40-acre field. Each sub-sample was collected using specialized tractors designed for use in sugarcane fields. The sub-samples were collected as close composite samples by collecting soils from adjacent to each of the four tires of the sampling vehicle. All of the sub-samples were combined into a single sample and thoroughly homogenized and placed into sample containers for analysis.

The composite sample provides a good estimate of the average concentration of chemicals over a large area. Sampling of such large areas would be infeasible using simple discrete sampling techniques. Using discrete samples, the number of samples required would be too large and the collection and analysis costs would be economically infeasible. Composite samples provide a good compromise between reduced cost and sample coverage, especially for use in assessing ecological risk within areas where only non-point source contamination from application of agrochemicals is expected.

As discussed in previous sections, agricultural fields were stratified into three separate land uses based on professional judgment of the relative intensity of agrochemical usage. Sugarcane fields with a history of row crop farming for vegetables were sampled at a higher density (50%) than sugarcane fields without a history of row crop farming (20%). Citrus groves were similarly sampled at a 50% density. A more detailed description of the process used to identify fields with a history of vegetable row-cropping is provided in the ESA.

A total of 1,191 40-acre composite surface soil samples were collected as part of the due diligence evaluation. These samples were collected from all four sugarcane areas and the three citrus groves as follows (Figure 3.1-1):

- Sugarcane Fields
  - Area 1 - 141 samples
  - Area 2 - 389 samples
  - Area 3 - 261 samples
  - Area 4 - 163 samples
  - 204 samples collected from former row-crop fields.
  - 750 samples collected from fields without a history of row-cropping.
- Citrus Groves
  - Dunwoody - 32 samples
  - Devils Garden - 45 samples
  - Southern Division - 160 samples.

All 40-acre composite samples were analyzed for a wide range of agrochemicals. The sample analyses were completed by Columbia Analytical Services, Accutest Labs and E-Labs at Florida facilities. Each 40-acre composite sample was analyzed for the following groups of chemicals.

- organo-chlorine pesticides;
- organo-phosphorous pesticides;
- chlorinated herbicides;
- metals; and
- total organic carbon.

All data were subject to review and validation using the FDEP's Automated Data Processing Tool (ADaPT) and validated data were included in the project database. A complete description of the data review process is presented in the ESA. The entire database of 40-acre composite surface soil samples used in this ERA is provided in Appendix A of this document.

A summary of the analytical results is presented in Table 3.1-1 through 3.1-7 for sugarcane Areas 1 through 4 and the three citrus groves. Tables 3.1-8 and 3.1-9 present a summary of the analytical results for sugarcane fields with and without a history of row-cropping. A total of

34 chemicals were detected in 40-acre composite samples including 9 inorganic chemical, and 25 organic chemicals (Table 3.1-10).

Summary statistics are provided for all detected chemicals for sugarcane Areas 1 through 4 and the three citrus groves in Tables 3.1-11 through 3.1-19.

3.2 5-Acre Discrete Surface Soil Samples

The District has completed a large number of ESAs for property acquisition due diligence evaluations. This experience has allowed the District to refine sampling techniques to target areas of concern using sampling techniques other than the composite samples discussed in the previous section. One case is the sampling of copper in citrus groves.

Copper sulfate is a fungicide widely used in citrus farming for the control of canker disease. The District has subsequently observed elevated copper concentration in citrus grove surface soils at a number of properties. Because of the prevalent observations of elevated copper concentrations in citrus groves evaluated by the District, the Protocol provides for sampling of citrus grove soils for copper using a higher density of samples and replaces the composite sample technique with 5-acre discrete samples.

The 40-acre fields in the three citrus grove tracts discussed in the previous section were subdivided into eight grid cells five-acres each. One close composite ‘discrete’ sample was collected from each grid cell. These discrete samples differ from the composite samples collected from the 40-acre fields because the sample represents only the small area from which the sample was collected rather than the average chemical concentrations from the entire 40-acre field.

The discrete samples are actually small-scale composite samples. One subsample is collected from three areas near the sample location in order to obtain an estimate of average concentration of the areas most likely to be affected by the application of agricultural chemicals used in citrus farming. Discrete soil samples were composed of three equal-volume subsamples; one subsample each from: (1) the drip line of the tree nearest to the nominal sampling point; (2) the nearest drainage swale to the tree; and (3) the nearest crown of the road between rows of the trees.

Discrete surface soil samples were collected from 50% of fields within each of the three citrus grove tracts. Data analysis on the 5-acre discrete samples was limited to copper using USEPA Method 6010. These data were validated using the FDEP ADaPT software and only validated data were used in the ERA. All 5-acre discrete data used in the completion of the ERA are provided in Appendix B of this document.

A total of 1,927 samples were collected with 357 collected from Dunwoody, 281 from Devil's Garden and 1,289 from Southern Division (Figure 3.2-1). Copper was detected in samples from all three areas and the data are summarized in Table 3.2-1.

3.3 Bulk Bioassay Samples

Based on professional judgment, the District elected to collect a number of bulk soil samples for use in the ERA. These samples are typically reserved until after the SLERA has been completed. However, given the time frame available for the completion of the due diligence evaluation and the District's experience conducting ESAs and ERAs on similar properties, the District collected samples directed toward typical ERA issues for the agriculture land uses of the USSC property.

A total of 13 bulk samples (Figure 3.3-1) were collected to provide soils to NewFields' laboratory in order to conduct toxicity testing, bioaccumulation testing and pore water analysis based on testing procedures outlined in the Protocol. The bulk soil samples were collected from as close as possible to the original eight sub-sample locations within the targeted field.

The goal of these samples was not to delineate chemical concentrations but rather to replicate the concentrations identified in the 40-acre composite sample from the field. The fields selected for bulk sample collection were selected based on chemical characteristics targeted by the ERA.

Sample size was dependant on the testing needs for each sample and ranged from 1 to 8 gallons. Each sample was made up of eight equal aliquots combined in a large mixing tub. To verify that the soils within the bulk sample were good approximations of the target chemical signature and that the concentrations were consistent throughout the sample, three verification samples were collected from each bulk sample. Verification samples were shipped to Spectrum Laboratories in Tampa, FL for chemical analysis. The bulk samples were shipped to NewFields Laboratories in Port Gamble, WA for further testing as described in Section 6.2.

Bulk soil sampling locations, tests for which samples were collected are shown in Table 3.3-1.

The results of the verification sampling are presented in Table 3.3-2 and are compared to expected concentrations in Table 3.3-2.

3.4 False Negative Samples

The primary disadvantage of composite samples is the possibility of masking hot spots by diluting the elevated discrete samples with cleaner aliquots. This masking can be viewed as a form of a "false negative," i.e., the probability of yielding clean composite results, while certain portions of the grid may exceed ecological benchmarks. In order to minimize the above disadvantage, samples termed "false negative samples" were collected per the Protocol. A representative percentage of "clean" fields (i.e., chemical concentrations within the 40-acre composite sample are all below the benchmark values) were selected for further evaluation. A total of 26 40-acre fields were sampled consisting of 19 fields from sugarcane (Figure 3.4-1). Fields within the sugarcane were further subdivided with 10 samples collected from fields with a history of vegetable farming and 9 collected from fields with no history of vegetable farming. An additional 7 fields within the citrus groves were sampled.

All of the individual sub-sample locations making up the eight-point composite samples within the selected grids were re-collected and analyzed for metals and OCPs. The results for the discrete samples for selected clean grids are provided in Appendix A of this document. The samples are summarized and evaluated in Section 5.1.1.

4.0 SCREENING LEVEL BENCHMARKS

In order to identify COPECs, upper-bound concentrations of chemicals are compared to screening-level ecological benchmarks. These benchmarks are receptor-specific and provide a simple tool to quickly identify chemicals that require additional risk-based evaluation.

Two types of benchmarks are used in the SLERA to identify COPECs. Sediment Quality Assessment Guidelines (SQAGs) were used to identify COPECs for the aquatic community receptor discussed in Section 2.1. Risk-based concentrations (RBCs) were used as screening-level benchmarks for aquatic-feeding wildlife. The following sections describe the derivation and use of both types of benchmarks.

4.1 Sediment Quality Assessment Guidelines

Screening is conducted for two general sets of ecological receptors and the screening values are used to identify areas that may require further attention for each receptor. For the aquatic community receptor, the FDEP's SQAGs for Florida Inland Waters (MacDonald et al. 2003) were used according to the Protocol as screening values where available.

The SQAGs were developed for assessing sediment quality in Florida waters, based on the probability of effects on sediment-dwelling organisms. For each contaminant there are two SQAGs: Threshold Effect Concentration (TEC) and Probable Effect Concentration (PEC). TECs were formulated to define concentrations of contaminants below which adverse effects on sediment-dwelling organisms are unlikely to occur. PECs were developed to define ranges of concentrations above which adverse effects are likely to occur.

The TEC serves as the initial screening value. Table 4.1-1 presents the list of chemicals detected in 40-acre composite samples throughout the property. The table also provides the TEC and PEC SQAGs where they are available.

For some contaminants, SQAGs have not yet been developed. The Protocol indicates that the USEPA's Ecotox Thresholds, the National Oceanic and Atmospheric Administration's Effects Range Low and Effects Range Median, or other ecologically-based guidelines should be used when SQAGs are not available. Chemicals exceeding either the TEC or the PEC, or their equivalent benchmark where SQAGs are not available, are identified as COPECs and are further discussed in this ERA.

4.2 Risk-Based Concentrations

Since TECs/PECs are specific to benthic macroinvertebrates, screening is also conducted for aquatic-feeding wildlife. RBCs for aquatic-feeding wildlife were calculated by estimating the potential exposure of the receptors discussed in Section 2 to chemicals through the ingestion of aquatic prey species that might accumulate chemicals from soils after they have been flooded. Exposure and RBCs were calculated for aquatic-feeding wildlife using a fugacity-based food web model developed for the District specifically for the purposes of the CERP program (Goodrich 2002 and NewFields 2006). The model provides conservative (i.e., protective) exposure estimates for key species of wildlife that occur in central and southern Florida. The model was developed to incorporate potential bioaccumulation of organic and inorganic chemicals into an aquatic food web that could develop at a flooded agricultural site. The model has been approved by the USFWS for use by the District in making decisions regarding property acquisition. Full documentation for the food web model is provided in Appendix C.

Exposure estimates, generated by the model, are compared to Toxicity Reference Values (TRVs) which represent estimated levels of toxicity based on specific toxicological endpoints for test organisms. For calculation of screening-level RBCs, no-observed-adverse-effects-level (NOAEL) TRVs that represent exposure rates at or below which no adverse effects are expected, were used.

The model also includes lowest-observed-adverse-effects-levels (LOAELs) that represent exposure rates at the lowest exposure rate evaluated in the referenced toxicity studies that was associated with adverse effects. LOAEL TRVs were not, however, used for screening-level RBC calculations but are discussed further in Section 6. The true threshold for effects lies between the NOAEL and LOAEL TRVs.

RBCs were calculated for the entire list of receptors discussed in Section 2 using the NOAEL TRV. The lowest RBC was identified as the screening-level benchmark and is intended to be protective of all aquatic-feeding wildlife species. If chemical concentrations in the agricultural parcels do not exceed the RBC, the chemical is not identified as a COPEC and the potential for unacceptable risk to aquatic-feeding wildlife from that chemical is considered to be *de minimis*. If concentrations exceed the RBC, the potential for unacceptable risk cannot be conclusively ruled out and the chemical is identified as a COPEC and is evaluated further in this ERA.

For organic chemicals, the calculation of RBCs is dependant on the total organic carbon (TOC) content in soils. TOC content is important because organic chemicals tend to bind tightly to organic carbon in soils limiting the bioavailability of the chemical. If the chemical has limited bioavailability, then the potential for bioaccumulation up the food chain is lowered. This is an important consideration for the USSC properties where the soils range from sandy soils, with very limited organic carbon content, to muck soils that are highly organic.

An analysis of the TOC content in the soils from the agricultural parcels is presented in Appendix C. The analysis used a geostatistical approach to identify sub-populations of TOC data and determine the median TOC within each sub-population. The results of the statistical analysis closely tracked the soil types located in the agricultural lands and identified five separate sub-populations based on TOC. As a result, five median TOC values were used to estimate RBCs for organic chemicals and the RBCs are specific to the areas of the site that fit within each TOC sub-population as delineated in Appendix C. The areas of the property that fall within each TOC sub-population are shown in Figure 4.2-1 for sandy soils and 4.2-2 for muck soils.

Soil TOC content is not considered in the model when calculating RBCs for inorganic chemicals. Therefore, only one RBC for each inorganic chemical was calculated and used for screening. All inputs to the model are provided in Appendix C. For those detected chemicals that lack default values in the model or those default values that were modified for RBC calculations, TRVs were obtained from literature sources and are discussed in Appendix C. Finally, all RBC calculation output files and the complete model documentation that provides all of the equations and underlying assumptions of the model are provided on compact disc (CD) in electronic format as part of Appendix C.

RBCs calculated for organic chemicals are provided in Table 4.2-1 and those for inorganic chemicals are provided in Table 4.2-2.

5.0 SCREENING-LEVEL ECOLOGICAL RISK ASSESSMENT

The Protocol indicates that COPECs should be selected from the list of chemicals detected in the agricultural areas of the property. COPECs are selected based on conservative assumptions using maximum detected concentrations and screening-level benchmarks for each group of receptors. Selection as a COPEC does not necessarily indicate unacceptable risk to the receptor, but rather that the risk could not be conclusively ruled out. Chemicals identified as COPECs are discussed in more detail in Section 6, the Risk Characterization, where the potential risk for unacceptable effects to the future aquatic community and/or aquatic-feeding wildlife is presented.

Section 5.1 presents the COPEC selection process for the aquatic community receptor while COPECs for the aquatic-feeding wildlife receptors are presented in Section 5.2.

5.1 Aquatic-Community

COPECs for the aquatic community receptor were selected using a conservative, three-step process. This process differed slightly from the process outlined in the Protocol, but the changes were necessary due to the size of the USSC agricultural areas.

First, the entire dataset was screened and chemicals that were detected in 10 or less agricultural area 40-acre composite samples (<1%) were removed from consideration as COPECs. While the potential for risk to the aquatic community from these chemicals cannot be dismissed, it is highly unlikely that widespread risks to receptors in WRPs would be present from such infrequently detected chemicals. Chemicals excluded from further analysis based on limited detections included; 2,4,5-TP (n = 2), chlorpyrifos (n = 3), endrin aldehyde (n = 1), heptachlor (n = 2), pentachlorophenol (n = 2) and terbufos (n = 2).

The second step in the COPEC selection process is a comparison of maximum detected concentrations of chemicals in each major area of the agricultural parcels to the TEC-SQAG. These comparisons are presented in Table 5.1-1 for sugarcane areas and 5.1-2 for citrus grove areas and resulted in a total of 22 chemicals (6 inorganic and 16 organic chemicals) being carried forward to the COPEC identification process. These chemicals included; arsenic, barium, copper, chromium, mercury, silver, aldrin, atrazine, chlordane, 2,4-D, 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, dieldrin, endrin, endrin ketone, endosulfan I, endosulfan II, endosulfan sulfate, g-BHC, heptachlor epoxide, and toxaphene. Those chemicals whose concentrations did not exceed the TEC-SQAG were removed from further consideration as COPECs.

Finally, the 95th (upper confidence limit) UCL of the mean concentration within each major area of the agricultural parcels was also compared to the TEC-SQAG (Tables 5.1-1 and 5.1-2). The chemicals with 95th UCL concentrations greater than the SQAG in any area were selected as COPECs for the aquatic community receptor. Those that did not have a 95th UCL exceedance in any of the major sugarcane or citrus areas were removed from further consideration as COPECs. The chemicals removed based on this approach were: arsenic, chromium, mercury, silver, aldrin, endosulfan I, endosulfan II and g-BHC. In all cases, detected concentrations of these chemicals exceeded TEC benchmarks infrequently and exceeded PEC benchmarks in 2 or less of the greater than 1,000 total 40-acre composite samples. Any potential for elevated risks from these chemicals are expected to be isolated to small areas and are not likely to have adverse effects on the aquatic community.

The following remaining chemicals were identified in at least one major sugarcane area or citrus grove and were selected as COPECs:

- Barium;
- Copper;
- Atrazine;
- Chlordane;
- 2,4-D;
- 4,4'-DDD;
- 4,4'-DDE;
- 4,4'-DDT;
- Dieldrin;
- Endosulfan Sulfate;
- Endrin;
- Endrin Ketone;
- Heptachlor Epoxide; and
- Toxaphene.

Figures 5.1-1 through 5.1-14 present the 40-acre composite sample data from all agricultural area sampling locations for the COPECs compared to TEC and PEC SQAGs. The potential risks to the aquatic community receptor from the COPECs are discussed in detail in Section 6. Additionally, since copper was also sampled using the 5-acre discrete sampling approach discussed in Section 3, those data were also mapped in comparison to the copper TEC and PEC SQAGs in Figures 5.1-15 and 5.1-16.

Several other chemicals were detected in agricultural area soils, but no SQAG benchmarks or their equivalents were identified. In sugarcane areas, 2,4,5-T, ethoprop and selenium were detected but lacked screening-level sediment benchmarks. Data for these for chemicals were reviewed to determine if they warranted selection as COPECs.

Detectable concentrations of 2,4,5-T, an herbicide, were observed in 8 of 261 samples in Area 3 and in 1 of 163 samples in Area 4. It was not detected in Areas 1 or 2. Review of aquatic toxicity data indicates that 2,4,5-T is classified as slightly toxic based on the average acute toxicity for all tested species groups (Kegley et al. 2008a). Based on the small number of detections and the relatively low toxicity rating, 2,4,5-T was not selected as a COPEC for the aquatic community receptor.

Ethoprop was detected in 23 of 953 total sugarcane area samples (2.4%) and was not detected in the 237 total samples from the citrus groves. Review of aquatic toxicity data indicates that ethoprop is classified as moderately to highly toxic (Kegley et al. 2008b) but given the small number of detected concentrations and short half life (approximately 25 days), it is unlikely to cause widespread risk to the aquatic community and it was not selected as a COPEC for the aquatic community receptor.

Finally, no sediment screening values for effects to the aquatic community receptor are available for selenium. Aquatic-feeding wildlife are, however, expected to be the more sensitive receptor for selenium-based effects and selenium was selected as a COPEC for that receptor.

5.1.1 False Negative Analysis

As noted in the Protocol, composite sampling has the potential to mask hot spots by diluting the elevated concentrations in subsamples with cleaner aliquots. This masking can be viewed as a form of a “false negative” (i.e., the probability of yielding clean composite results, while certain portions of the grid may exceed ecological benchmarks). To ensure the reliability of the resulting decisions, a number of “clean” fields (i.e., those fields whose COPEC concentrations in composite samples collected within the grid are all below the SQAG-TEC values) were selected from various parts of the investigated parcels for conducting the false negative analysis prescribed in the Protocol. These samples included both citrus groves and sugarcane fields.

The results for the composite samples for selected clean grids were tabulated, along with the results for individual discrete samples for the following analytes: Copper, a-Chlordane, g-Chlordane, 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, Dieldrin, Heptachlor Epoxide, and Toxaphene. These represent the COPECs with detected concentrations above their respective PECs in one or more 40-acre composite samples. Endrin and endrin ketone were not included in the false negative assessment because their maximum detected concentrations did not exceed their respective PECs. Atrazine and endosulfan sulfate do not have PEC benchmarks available and were similarly not included in the false negative analysis.

For each grid, the percentage of discrete samples exceeding their corresponding PEC was calculated. The grids were sorted based on their ascending composite concentration. The average aliquot exceedance rate for each grid was then computed by obtaining the average percentage of aliquots exceeding the PEC in that grid and in all grids with lower composite concentrations.

The average aliquot exceedance rates were then used to determine the composite sample concentration above which the individual sample results exceed the composite value by 5%. The largest composite value corresponding to 5% exceedance rate was defined as the trigger level. If the trigger level was less than the PEC for the given chemical, it was used in all subsequent analyses as the substitute for the PEC. This process was performed based on the adjusted reported concentrations, whose non-detects are set as equal to one-half of their corresponding detection limits, as well as based on reported values whose non-detects are set as 0.

The results of the false negative analysis for the above listed analytes are reported in Tables 5.1-3 through 5.1-11, respectively. As the results indicate, for all investigated analytes, the rates of false negatives are less than 5%, and thus, the current PEC values do not require any adjustment.

5.2 Aquatic-Feeding Wildlife

The list of COPECs was selected for aquatic-feeding wildlife using a similar approach as discussed in the previous section for the aquatic community receptor. However, because of the presence of threatened and/or endangered species within the list of wildlife receptors being considered a more conservative approach was taken to select COPECs that require further evaluation.

As discussed in Section 4.2, there are a number of soil types present in the agricultural areas of the site. These soil types contain widely varying levels of organic carbon, measured as TOC. The amount of TOC in soils has a direct relationship on the RBCs calculated for organic chemicals using the fugacity-based food web model. As a result, RBCs were calculated using NOAEL-TRVs for each of the five TOC sub-populations. These RBCs, that represent the RBCs for the most sensitive or limiting receptor, are presented in Table 5.2-1 along with maximum concentration of each detected chemical from all samples within that TOC sub-population area in each major sugarcane area. The same information is presented for the citrus groves in Table 5.2-2. All RBCs calculated for all receptors are presented in Appendix C.

Organic chemicals were selected as COPECs if the maximum detected soil concentration was greater than the lowest NOAEL-based RBC in at least one TOC sub-population. The chemicals selected as organic COPECs were; 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, endrin and toxaphene. The breakdown of organic COPECs based on TOC sub-population type is shown in Table 5.2-3. All other detected chemicals shown in Tables 5.2-1 and 5.2-2 were removed from further consideration as COPECs and are not discussed further in this document.

Maximum detected concentrations of inorganic chemicals are compared to screening-level RBCs in Table 5.2-4 for sugarcane areas and 5.2-5 for citrus groves. The food web model for inorganic chemicals is not fugacity-based and does not, therefore, depend on the TOC of the soils. As a result, only one RBC is presented for each chemical and the RBCs presented in Tables 5.2-4 and 5.2-5 are representative of the lowest NOAEL-based RBC calculated for all receptors. For copper (85 mg/kg) and selenium (2 mg/kg), the RBCs used are project-specific benchmarks based on consensus with USFWS. The copper benchmark was identified by the District and the USFWS for use as a screening value for the protection of the Everglades snail kite. The selenium benchmark was suggested for use as a conservative screening-benchmark for protection of aquatic-feeding birds.

Arsenic, copper and selenium exceeded the lowest NOAEL-based RBC in at least one sample in the citrus areas and were selected as COPECs. Maximum detected concentrations of barium, cadmium, chromium, lead, mercury, and silver were removed from consideration as COPECs and are not discussed further in this document.

The following chemicals were selected as COPECs for the aquatic-feeding wildlife receptor and are discussed in greater detail in Section 6:

- Arsenic;
- Copper;
- Selenium;
- 4,4'-DDD;
- 4,4'-DDE;
- 4,4'-DDT;
- Endrin; and
- Toxaphene.

Comparisons of all 40-acre composite samples for organic and inorganic COPECs to their respective RBCs are presented in Figures 5.2-1 through 5.2-8. Additionally, since copper was also sampled using the 5-acre discrete sampling approach discussed in Section 3, those data were also mapped in comparison to the 85 mg/kg copper benchmark in Figures 5.2-9 and 5.2-10.

No default RBCs were available in the food web models for 2,4,5-T, pentachlorophenol or terbufos. Because of the small number of detections for each of the chemicals, low level detections, and a lack of adequate toxicity information from which to derive a TRV, no RBCs were calculated. Risks to wildlife receptors from these three chemicals are expected to be low.

6.0 RISK CHARACTERIZATION AND CATEGORIZATION

This ERA is intended to provide the District with information regarding the potential ecotoxicological risks associated with residual agrochemicals present in the sugarcane fields, row crop areas and citrus groves throughout the USSC property. The conclusions can be used by the District as part of their broad due diligence evaluation supporting the purchase of the property from USSC. Given the scale of the property and the time allotted for the due diligence evaluation, the Phase I and Phase II ESAs, of which this ERA is a supporting document, were not designed to support corrective action decisions for any specific WRPs that might be conducted in the future on the USSC properties. Rather, the ERA was designed to support the District's property acquisition decisions by providing an assessment of potential risks to future ecological receptors focused on observable trends in the data and to provide a risk-based categorization of properties to assist the District in estimating potential corrective action costs within WRP footprints when they become available.

The risk-based categories discussed in this section provide the District with information regarding the potential need for remedial activities within the agricultural parcels should WRPs be constructed in those areas. The risk-based categories are not intended as final recommendations for corrective action. They do, however, provide information on the possible extent of corrective actions and the likelihood that such actions may be necessary.

Should the District decide to purchase the USSC properties, an expanded ERA may be needed for individual WRPs for which the footprint includes areas identified as potentially requiring corrective actions. These expanded ERAs typically include data collection and laboratory analyses of bioavailability, toxicity and/or other data relevant to the site-specific ERA needs. The data from the expanded ERA will then be used to more closely define areas requiring corrective action based on site-specific calculation of ERA benchmarks.These ERAs are, however, outside of the scope of this document.

In order to provide the District with the necessary information as described in the preceding paragraphs, the agricultural areas of the USSC property were divided into three categories based on the potential ecological risk. The categories are defined as follows:

> **Category 1**: Moderate or intensive corrective actions are not necessary for WRPs with acceptable levels of ecological risk to aquatic life and aquatic-feeding wildlife.

> **Category 2**: Moderate or intensive corrective actions may be necessary for WRPs with acceptable levels of ecological risk to aquatic life and aquatic-feeding wildlife.

> **Category 3**: Moderate or intensive corrective actions are required for WRPs with acceptable levels of ecological risk to aquatic life and aquatic-feeding wildlife.

In addition to purchasing decisions, the categorization could help in identifying the scope and scale necessary for future ERAs associated with WRP siting and design. For example, in areas designated as Category 1, the necessary scope of future ERA tasks may be limited. Similarly in ERA Category 3, the scope of necessary ERA tasks may be limited should the District choose to initiate corrective actions based on the conclusions of this report.

Assignment of lands to the three categories was accomplished by incorporating data from multiple lines-of-evidence and is supported by the Protocol. Phase II ESA data were analyzed using a detailed and advanced geospatial statistical analysis (Section 6.1). Uncertainties related to SQAG benchmarks in site soils, particularly in the highly organic muck soils that make up a large part of the agricultural areas, were addressed using standard aquatic toxicity bioassays (Section 6.2.1). The potential for the bioaccumulation of chemicals into a future aquatic food web was studied using both pore water analyses and laboratory bioaccumulation testing (Sections 6.2.2 and 6.2.3). A detailed analysis of the carbon content in the agricultural area soils was conducted on a subset of samples in order to assess the potential bioavailability of COPECs in soils that may become inundated and converted to sediments (Section 6.3). And finally, calculation of risks to future aquatic wildlife using TRVs other than NOAELs was completed (Section 6.4). These analyses are all discussed in the Protocol as part of an expanded ERA and the results from each analysis are used to support the placement of project lands within the three categories.

In areas designated as Category 1, the scope of future expanded ERA tasks and for corrective actions is probably limited. In areas assigned ERA Category 3, the scope of expanded ERA tasks may also be limited if the District decides to initiate corrective actions based on the conclusions of this report. In areas assigned Category 2, additional expanded ERA tasks may be most beneficial in defining the extent of corrective actions required.

6.1 Geospatial Statistical Analysis

The composite and discrete soil samples were subjected to a thorough geospatial analysis. Upon validation, the collected data were compiled into a geographical information system (GIS) database. This extensive database includes more than 1,100 40-acre composite and nearly 2,000 5-acre discrete soil samples that have been laboratory analyzed for 86 analytes and chemical parameters. The available spatial and soil features information are also compiled into the GIS database.

6.1.1 Summary Grid Statistics

For risk evaluation purposes, the investigated zones were divided into 400-acre grids, as shown on Figure 6.1-1. Each grid is a 4,175 ft x 4,175 ft square, identified by its column and row number. Using Cartesian nomenclature, the southwestern-corner grid is identified as G-01_01, while the northeastern-corner grid is G-58_54 (i.e., 58^{th} column and 54^{th} row). The available COPEC data within each grid were then used to compute their corresponding average, maximum detect, standard deviation, and the 95% upper confidence limit of the mean (UCL).[1] For these calculations, two sets of summary statistics were generated. The first set reflect the adjusted concentrations, whose non-detects are set equal to one-half of their corresponding detection limits. The second set uses data, with non-detects set equal to zero. The analyte-specific grid results of composite and discrete data are provided in Appendix D.

6.1.2 Zonal Statistics

The review of spatial and soil features indicates that the investigated parcels can be grouped into four distinct geographical zones, as displayed on Figure 6.1-1. The investigated zones are:

- **Zone A** - consists of parcels dominated by citrus farms with sand;
- **Zone B** - located to the southwest of Lake Okeechobee, contains mainly sugarcane fields with sand soil; and
- **Zones C and D** - located to the south and the east of Lake Okeechobee, respectively, consist of sugarcane fields covered with muck soil. Large sections of these latter zones were formerly used as vegetable farms.

The statistical characteristics of composite samples of measured COPECs within each zone were investigated. The COPECs include metals (arsenic, copper and selenium) and pesticides (4,4'-DDD or DDD, 4,4'-DDE or DDE, 4,4'-DDT or DDT, and Toxaphene). Samples of results are displayed in Appendix D, Figures 1 through 20. As displayed on these figures, in addition to summary statistics, zone-, analyte-specific probability plots are generated. In these computations, unless noted, adjusted concentrations are used, whose non-detects are replaced by one-half of their corresponding detection limits. This subset of COPECs was selected for this more detailed analysis because they represent the primary COPEC risk drivers for one or both receptors. All COPECs are used to categorize risk using the 400-acre grids discussed in the previous section, however, this list of COPECs were analyzed in more detail in the geospatial analysis based on the extent of contamination and potential for risk.

A probability plot, as noted in Department of the Navy (DON 2002), is a graph of data versus the quantiles of a user-specified distribution, which are often used to: (1) to determine how well data fit a hypothesized distribution (e.g., lognormal or normal), (2) to identify outliers, and (3) to

[1] For analytes with more than 4 reported values in a given grid, grid-specific UCLs are calculated based on Student's t distribution. Otherwise, average values are used as surrogates for UCLs along with the maximum detected values.

identify separate populations within the dataset and thus determine which of the subpopulations represent background concentration ranges. Data sets can contain samples from areas impacted by potential impacts, as well as measurements representing multiple types of natural and/or anthropogenic background concentrations. The presence of these multiple populations in a data set results in a segmented probability plot. Therefore, probability plots can be used to assess whether the measurements should be separated into different sub-populations. A change in the slope, existence of an inflection point, or gaps in a probability plot could indicate the threshold values separating different populations in the investigated dataset.

The main findings of zonal investigation are:

- The investigated COPECs throughout the investigated parcels, as well as within each zone, display mixtures of distinct statistical sub-populations. The presence of certain of these sub-populations is likely attributable to combinations of naturally-occurring and/or anthropogenic background concentrations, associated with historic agricultural applications.
- In comparison to other zones, the investigated COPECs within Zones C and D display higher concentrations. These elevated measurements can be attributed to their zonal historic land use and muck soil type. Former vegetable fields are especially prone to contain higher concentrations of certain COPECs, such as copper and DDE.
- The investigated COPECs within sand soil areas of citrus and sugarcane have lower concentrations when compared to the rest of the investigated parcels.

6.1.3 Zonal Geostatistics

To decipher the spatial characteristics of the investigated COPECs, the measured composite data within each zone are subjected to a thorough geostatistical analysis. In all of these computations, unless noted, adjusted concentrations are used, whose non-detects are replaced by one-half of their corresponding detection limits.

Geostatistics is a collection of techniques for the analysis of spatially correlated data. These techniques incorporate the spatial characteristics of actual data into statistical estimation processes. Geostatistics permit the performance of critical tasks, such as: optimization of mapping of spatial variables, estimating average block values, and the optimal design of sampling and monitoring schemes.

Environmental field data from a given site usually display a wide range of variability. Such erratic variations have led many to use classical (i.e., non-spatial) statistical estimation methods. These methods assume the collected data to be unbiased, unclustered, and independent (i.e., devoid of any correlational structures). In practice, however, field data are often collected in a biased fashion, are clustered around critical locations, and are expected to display a degree of spatial structure. Geostatistics recognizes these properties and, according to well-defined criteria, provides the statistical tools for:

- Calculating the most accurate estimations based on sample results and other relevant information;
- Quantifying the accuracy of these estimations;
- Generating equally-likely realizations of a random field conditional to the available field measurements; and
- Selecting the variables and locations to be sampled, if necessary.

EPA has taken the lead in promotion of geostatistics by producing the first public-domain software package, known as GEO-EAS (Geostatistical Environment Assessment Software) developed by Englund and Sparks (EPA/600/4-88/033a, 1988). This package was followed by another USEPA package, known as GEOPACK, developed by Yates and Yates (EPA/600/8-90/004, 1990). The successful results of application of GEOEAS prompted the USEPA to recommend its use in spatial environmental data analysis, as stated in "Guidance for Data Usability in Risk Assessment" (EPA/540/G-90/008, 1990a) and "Basics of Pump-and-Treat Ground-Water Remediation Technology" (EPA/600/8-90/003, 1990b). The American Society of Testing and Material (ASTM, 1994, 1996) has issued a series of standard guides for geostatistical site investigations.

The result of the geostatistical analysis is a series of geospatial estimations of COPEC concentrations across the site, thus ‘filling in’ the spaces between samples using advanced statistical techniques such as kriging.

Kriging is conducted by using variogram analysis. To construct the sample variogram, all pairs of measurements are identified. If there are n measurements, there are n(n -1)/2 pairs (e.g., 100 measurements yield 4,950 pairs). For each pair of measurements, three values are calculated: (1) one-half of their squared difference, (2) their separation distance, and (3) the relative geographical orientation of two measurement points. Having computed all the pair values, the sample variogram can be constructed. Kriging results are then computed using the GIS. A detailed discussion of the geospatial statistical analysis and methodology is provided in Appendix D.

6.1.3.1 Geostatistical Findings

Zone-specific variograms of investigated COPECs are displayed in Appendix D, Figures 21 through 27, [2] while their geostatistically interpolated (kriging) maps are shown on in Appendix D, Figures 28 through 34. The main findings are:

- Most of the primary COPECs display zone-specific variograms with various degrees of spatial structure. Copper is especially noted for its strong spatial structure. Such patterns can be attributed to homogeneity of historic land uses and soil types within the investigated parcels.
- Kriged maps of COPECs display different spatial patterns. For example, some like copper and DDE have distinct elevated areas, which can be related to their historic land use and soil type.
- In contrast, toxaphene data in all the investigated parcels are dominated by non-detects with elevated detection limits. In fact, of 1,181 composite samples in the database, only 36 (or 3%) have detected concentrations. Such sporadic results can be attributed to difficulties by the laboratory in meeting risk-based analytical targets.
- Selenium displays a unique pattern that is different from other primary COPECs, which may be attributed to naturally-occurring background concentrations.

6.2 Risk-Based Bioassay Test Results

In light of the timeframe available to conduct the ERA, the District elected to proactively conduct some advanced toxicity and bioaccumulation testing normally associated with expanded ERA activities, anticipating that such data may be useful in reducing uncertainty regarding uptake and toxicity of the agricultural soils. This is especially important in muck soils typical of sugarcane and vegetable production areas because the unusually high levels of organic carbon in the soils could affect bioavailability beyond the assumptions underlying the SQAGs and the food web model.

Samples were collected to support three types of tests: sediment toxicity testing, bioaccumulation from sediment, and pore water testing. As discussed in Section 3, a total of 13 samples were collected for testing purposes. Table 6.2-1 shows the samples collected, tests conducted and rationale/intended use for each sample.

In general, tests were conducted to address uncertainties related to the use of generic benchmarks and bioaccumulation models in the ERA. The tests were selected partly based on

[2] Sample variograms are generated consistent with ASTM standards. When probability plots of COPECs (Appendix E, Figures 1 through 20) display a small number of elevated values, variograms are computed after excluding the elevated values. However, these values are used along with all available reported values in the geostatistical interpolation process (kriging).

knowledge of typical issues encountered in SLERAs at other similar sites and partially based on data received early in the ESA sampling effort. These samples were used to guide sampling locations to target the analytes and concentrations for which testing was planned.

The methods, results and conclusions of each of the three types of tests are described in the following sections. Detailed reports for each test type are provided in Appendices E (toxicity tests), F (bioaccumulation tests) and G (pore water analyses).

6.2.1 Toxicity Testing

In order to better understand the potential risk to benthic aquatic invertebrates from residual pesticides and other chemicals associated with historic agricultural use, a series of soil samples were tested using standard sediment toxicity testing procedures cited in the ERA Protocol. Tested soils were collected from targeted COPEC concentration ranges as described in Table 6.2-1. Not all targeted ranges were tested due to limited time available to identify, collect, and verify COPEC concentrations ranges in bulk samples collected for testing.

The need for sediment toxicity testing was identified primarily because of the potentially high organic carbon content of the muck soils that predominated in the USSC properties. Organic carbon in sediments is known to reduce the toxicity from metals and organic compounds (MacDonald et al. 2003) because the carbon binds the chemicals making them less available for exposure to aquatic organisms. The SQAGs were developed based on relatively low TOC concentrations of around 1 percent whereas muck soils routinely contain over 20 percent TOC making their use in these high TOC soils questionable.

Another aspect of the testing was to evaluate the potential impact of flushing sediments by flowing water conditions that would occur as the WRP are built and operated. Soils were acclimated or ‘aged’ in a subset of samples by a pre-incubation (7 days) of sediments in test water prior to introducing the test organisms. Pre-incubation water was removed and replaced (i.e., similar to ‘static renewal’ testing) with fresh water prior to starting the toxicity tests. The acclimation process was intended to help assess the differences between short-term conditions just after initial inundation of agricultural soils, and longer-term conditions after soils have been inundated and overlying water has been exchanged by flow-through conditions. Just after inundation, highly soluble and easily suspended (e.g., colloidal) particulates will enter the water column and be carried away as water is replaced under flowing water conditions. During this initial period aquatic life is absent or very limited. Sediment conditions after this initial period may differ in that highly soluble and mobile forms of agricultural chemicals will be diminished, along with normal mineral salts that can also be toxic to aquatic organisms. Testing of unacclimated soil was conducted in parallel to help assess the potential importance of this process on toxicity.

In accordance with the Protocol, toxicity tests included 10-day benthic tests with *Hyalella azteca* and *Chironomus dilutus*. The toxicity testing methods followed guidance provided in standard method ASTM E 1706-05, "*Standard Test Methods for Measuring the Toxicity of Sediment-Associated Contaminants with Freshwater Invertebrates*" (ASTM 2006) and USEPA method, "*Methods for Measuring the Toxicity and Bioaccumulation of Sediment-Associated Contaminants with Freshwater Invertebrates* (USEPA/600-R-99/064)" (USEPA 2000). These methods are detailed in Appendix E.

Test results were evaluated in two ways. First, mean survival or growth in the test treatments was compared to the controls using an analysis of variance (ANOVA) and Dunnett's t-tests to determine statistical significance and rank. Second, biological significance was determined using a numerical comparison of mean survival or biomass per survivor in the test treatment to that of the control. While Florida does not have specific numeric criteria for sediment tests, they have been developed for surface waters. According to paragraph 62-302.500(1)(c) of the Florida Administrative Code, "acute toxicity" is defined at concentrations greater than one-third of the 96-hour LC_{50}. The 1/3 96-hour LC_{50} is typically applied as 20% mortality. For chronic, non-lethal endpoints, the IC25 is recommended (the level at which the organisms exhibit a 25% reduction in a biological measurement such as reproduction or growth, relative to the control). For the purposes of this evaluation, toxicity will be defined as statistical significance, and 20% mortality (<80% survival) or a reduction in growth of 25%, relative to the controls.

There were no significant decreases in survival or growth for *H. azteca* exposed to the test soils, relative to the controls (Table 6.2-2). This was true for both acclimated and unacclimated treatments. Biomass in each of the test treatments was higher than that of the controls, with biomass per survivor ranging from 0.73 to 0.97 mg/individual. There were also no significant differences between any of the test treatments.

There were statistically significant decreases in *Chironomus* survival and growth, relative to the control (Table 6.2-3). Survival was 73.8% in both the acclimated and unacclimated soils from sample 4501 F. Survival was 70.0% in the unacclimated soil from 4501 JN West and 76.8% in the acclimated treatment. In each case, mean survival was statistically different mean from control survival and was <80%. Mean survival in the acclimated 4501 JN West sample was higher than that of the unacclimated treatment, indicating that after an initial period of adjustment from soil to sediment, survival in this treatment may increase to acceptable levels. Growth in both 4501 F and 4501 JN West was also significantly reduced, relative to the controls. Biomass per survivor for the unacclimated and acclimated treatments was 19% to 26% of the biomass observed in the controls, a reduction of 74% to 81%, well above the suggested 25% threshold.

Statistically significant reductions in growth of *Chironomus* were also observed in test treatments 4621 AE East and 001E2-5, with mean biomass of 1.299 and 1.323 mg/survivor, respectively. While growth in these treatments was statistically significantly different than that of the controls, biomass was 78% and 79% that of the controls, representing reductions of 22% and 21%, respectively. This is within the suggested limit of 25%. It should be noted that both samples were tested as unacclimated treatments and it is possible that acclimation to aquatic conditions prior to testing may allow for increased performance in the toxicity tests.

Overall, the toxicity test results appear to reflect the impact of relatively high organic carbon content of muck soils. Toxicity was not observed in any sample that contained all individual COPEC concentrations less than ten times the PEC (Tables 6.2-2 and 6.2-3), or an average PEC-Q less than 3 (Table 6.2-4). Previously in the absence of toxicity tests, corrective actions have been considered when individual PEC-Q values were greater than 1, or the 95th UCL of the mean was greater than the TEC. For the muck soils, the toxicity test results indicate a lack of toxicity at concentrations above this range. This result was considered in setting the criteria for the categorization process discussed in Section 6.0.

6.2.2 Bioaccumulation Tests

The transition from a terrestrial to an aquatic ecosystem can significantly change the relative bioavailability of chemicals. Chemicals that may be tightly bound and non-bioavailable in soils may be soluble in water and have increased bioavailability in an aquatic ecosystem. This is particularly problematic for some persistent agrochemicals such as DDT and its metabolites. These chemicals, once inundated, can bioaccumulate through the aquatic foodchain and present a risk not only to lower trophic level receptors living in the water, but to upper trophic level receptors that may eat animals that have bioaccumulated COPECs.

Samples from various USSC properties were submitted to standard sediment bioaccumulation testing (Table 6.2.1). The initial goal was to test samples that represent the range of TOC and bioaccumulative COPEC concentrations. As prescribed in the Protocol, soils were tested using the standard approach described in "*Methods for Measuring the Toxicity and Bioaccumulation of Sediment-Associated Contaminants with Freshwater Invertebrates* (USEPA/600-R-99/064)" (USEPA 2000), and using the standard test organism *Lumbriculus variegatus*. Results of bioaccumulation tests were compared to results from the food web model that was developed for CERP projects by the District and USFWS (Goodrich 2002 and NewFields 2006). The results are shown in Table 6.2-5 and in Appendix F.

For several of the organic analytes, concentrations in test organisms were not detectable, making conclusions based on comparisons to model results uncertain. DDE is one of the most important OCPs tested because it is one of the most widespread, and of highest concentrations in the USSC properties tested. Concentrations of DDE detected in the test organisms were consistently, and sometimes substantially, lower than the concentration predicted by the food web model for benthic invertebrates. The ratio of modeled:measured ranged from 3.3 to over

700 (Table 6.2-5). Excluding the highest and lowest ratios, the average ratio for the remaining two samples is about 20.

Overall these results indicate that the food web model used to generate RBCs probably overpredicts exposure and risk and is adequately protective for use in the USSC property assessment. The exact degree of over-prediction is difficult to quantify based on the available data, but is likely to be considerable. RBCs were not re-calculated using the bioaccumulation test results, but the potential margin of protectiveness was considered in developing the criteria for assignment of properties into the three categories discussed in Section 6.0.

6.2.3 Pore Water Tests

As a further mechanism for testing the results output by the food web model, a number of samples were also collected and analyzed for pore water concentration. Pore water chemical concentrations form the basis of all fugacity-based calculations performed by the food web model. Pore water concentrations are used to estimate surface water concentrations and bioaccumulation rates into the lowest trophic level receptors in the model.

To measure pore water concentrations, water from the interstitial spaces between the soil particles must be collected. It is in these spaces that the organisms at the bottom of the food chain are exposed to the chemicals and obtain the largest portion of the chemical that is concentrated in their tissues and passed upward through the food web when they are consumed by higher trophic level species.

Soil samples were inundated in the laboratory for a period of 14 days. At 7 days and 14 days post-inundation, overlying water was removed from the sediments and sediments were centrifuged to extract pore water. A complete discussion of the methods and test results is provided in Appendix G.

Results are shown in Table 6.2-5. Where chemicals were detectable in porewater samples, concentrations were often higher than predicted by the food web model. If comparable, this could mean that the food web model underpredicts the COPEC concentrations in porewater to which benthic invertebrates are exposed. However, the porewater in the model is based on theoretical predictions of freely-dissolved fractions based on partitioning coefficients (e.g., Kow) taken from the literature. The laboratory measurements were made on actual filtered (0.45 µm) samples and probably include chemical adsorbed to fine suspended particulates (i.e., colloid) and are not truly dissolved concentrations.

The *Lumbriculus* tissue samples should be considered a better basis than porewater measurements for evaluating the actually bioavailability of the COPECs. If the measured porewater were taken as the true representation of exposure point for the worms, then the empirical porewater→worm uptake coefficient from the laboratory tests should also be substituted in the model to ensure that both components are calibrated. In either case, model results appear to overpredict concentration of organic COPECs in *Lumbriculus*. It is unclear how the relationship to other benthic species would compare. However, *Lumbriculus* is a standard test species and is generally used to calibrate uptake models. Regardless, the model seems to remain a conservative (i.e., environmentally protective) tool for estimating exposure. These data were used to support the conclusion that the food web model was adequately conservative to calculate RBCs protective for all of the aquatic-feeding wildlife receptors considered in this assessment. Additional, site-specific testing may be needed when siting and designing WRPs to help ensure the best environmental protection and cost-effectiveness of the projects.

6.3 Carbon Analysis

As noted previously, the TOC content of soils or sediments are known to affect the bioavailability of both organic and inorganic contaminants due to adsorption or binding of contaminants to carbon surfaces. This is especially true for non-polar hydrophobic organic chemicals in the aqueous environments of sediments. It is also clear that various types of carbon have differing capacity for binding contaminants. Soot or black carbon resulting from burning of organic matter is known to bind organic chemicals more tightly than more organic forms of carbon (see Burgess et al. 2003 for a summary). For example, partition coefficients for binding of polynuclear aromatic hydrocarbons to black carbon resulting from fossil fuel burning are more than two orders of magnitude greater than for organic carbon.

Following annual harvest, the standing biomass from sugarcane fields is typically burned to prepare for the following season. If burning results in transforming substantial proportions of organic carbon to inorganic or soot carbon forms, measures of TOC may underestimate the binding capacity of sugarcane field soils. To evaluate this possibility, the amount of soot carbon was analyzed in six representative soil samples. TOC and soot carbon was determined by modifications to EPA Method 9060 in soil samples. Results are presented in Table 6.3-1. Soot carbon content varied from 0 to 2.5 percent in soil samples that contained total organic carbon concentrations ranging from 0.5 to 32 percent. The soot concentrations are relatively low compared to other sites with industrial sediments that can contain up to 30 percent soot or black carbon, albeit due to burned fossilized fuels. The relatively few samples analyzed here are not adequate to derive a quantitative relationship. However, the samples indicate that consideration of this factor may important in more detailed bioavailability assessments during WRP project design. The carbon analysis report is provided in Appendix H.

6.4 Wildlife Risk Modeling

The RBCs calculated in Section 4 and used to identify COPECs in Section 5 were calculated using NOAEL TRVs from laboratory studies conducted on birds. The endpoints used in those studies were typically based on ascertaining the effects of the tested chemical on the growth or reproduction of the test birds.

The goal of the NOAEL RBCs used in COPEC identification is to provide a concentration or concentrations (values are TOC dependant) below which, no effects to the receptor are expected. However, exceedance of the NOAEL-based RBCs does not necessarily indicate unacceptable levels of adverse effects. Under USEPA guidance, exceedence of a NOAEL by screening-level exposure calculations would trigger additional risk analysis aimed at more accurate characterization of the potential for ecotoxicological effects (EPA 1997). Use of benchmarks corresponding to higher exposures and risk of effects is often useful to assess how site exposures compare to levels at which effects might be observed. The LOAEL-based TRVs are often used for this purpose because they represent the lowest concentrations where observable effects have been demonstrated. These TRVs are typically representative of effects to growth and/or reproduction that could have effects on the fitness of individual birds or if the effects are severe enough could reduce the long-term sustainability of the population of birds inhabiting an area. LOAEL TRVs that are used in ERAs are not typically based on mortality endpoints.

In order to address this issue in this ERA, both a NOAEL and a LOAEL TRV were identified for each COPEC and used to calculate two separate RBCs for each receptor and in each TOC sub-population. The NOAEL and LOAEL TRVs are provided in Appendix C. Care has been taken to select only TRVs representative of ecologically-relevant endpoints. While other effects may be predicted at lower exposure rates for some COPECs, such as biochemical changes, how those effects translate to ecologically relevant effects to individual birds or populations of birds is not known.

NOAEL and LOAEL RBCs were calculated for each of the list of 10 aquatic-feeding birds discussed in Section 2. Both RBCs were calculated for each of the five TOC sub-populations resulting in a total of 50 RBCs for each COPEC. Because of the complicated nature of comparing 50 RBCs to thousands of sample concentrations for each of the COPECs, the assessment was simplified to include only the lowest NOAEL and lowest LOAEL RBCs for each chemical in each TOC sub-population. The District's food web model was used to calculate all RBCs and all model output results are also presented in Appendix C.

This approach provides two benefits. First it simplifies the assessment and second it ensures that decisions made by considering the most sensitive receptor will be protective of all of the other receptors. This is important considering the special regulatory status that many of the receptors are afforded due to the threatened or endangered nature of their populations.

Table 6.4-1 provides a list of all of the lowest NOAEL and LOAEL RBCs calculated for each organic COPEC in each TOC subcategory. For copper and selenium, RBCs were not calculated using the food web model since both of these chemicals are compared to benchmarks reached via consensus with the District and the USFWS. For copper, 85 mg/kg was used as a benchmark for potential effects to the Federal endangered species, the Everglades snail kite. This benchmark was identified by District and USFWS representatives and is used to identify areas where risks to the snail kite due to copper exposure cannot be ruled out without further study. For the purposes of this evaluation, the 85 mg/kg benchmark is being treated as a NOAEL RBC and two times the benchmark (170 mg/kg) is being treated as an approximate LOAEL. Studies by the District and the USFWS are ongoing to determine the amount of copper accumulated in apple snail tissues in different soil types. These studies may be used to refine the benchmark in future assessments.

Similarly, a 2 mg/kg benchmark for selenium has been used for screening purposes on District projects. The benchmark was derived by Lemly (1997) and is generally assumed to be protective of reproduction effects in warm-water fish, and food chain based effects to aquatic-feeding birds. The District has evaluated selenium desorption from sediments in similar soils from the C-11 canal. Selenium concentrations up to approximately 7 mg/kg, when inundated for several months did not result in selenium concentrations in the overlying surface water greater than wildlife-based water quality benchmarks (NewFields 2008). Based on these studies and on discussions with USFWS, the NOAEL RBC was set at 4 mg/kg while the LOAEL RBC was set at 7 mg/kg for this ERA.

The RBCs discussed in this section are compared to soil concentrations to help determine the risk-based classification category into which each agricultural parcel is placed.

6.5 Chemicals Without Standard Analytical Methods

The agricultural areas currently owned by USSC are actively farmed for commercial sugarcane and citrus production. As a result, a wide list of pesticides, herbicides, fungicides and fertilizers are regularly used to aid in the productivity of the land. Chemicals within these products may have toxic effects on aquatic life once the land is converted from a terrestrial ecosystem into an aquatic ecosystem.

While the list of chemicals currently used by USSC is thought to include only those chemicals currently approved for use by the USEPA, the conversion of an agricultural field into a WRP is not considered as part of the pesticide registration process.

Many of the commonly used modern pesticides do not have standard analytical methods associated with them. As a result, many of the pesticides applied by USSC in their routine farm operation were not detectable in the Phase II ESA soil samples and could not be assessed in this ERA. The District is, however, addressing these pesticides by completing a thorough Best Management Practices (BMP) report for use by USSC should a phase-out period for pesticides and fertilizers be required prior to WRP construction.

The BMP uses a combination of application rate, soil degradation rate and potential aquatic toxicity to calculate a period that a chemical must not be used prior to completion of a WRP. The BMP is being completed on a list of all chemicals applied to agricultural fields as supplied by USSC. Toxicity and half-life information for those chemicals that could not be analyzed in the Phase II ESA samples is provided in Appendix I. The toxicity information is being used in the BMP, under separate cover, to reduce the risk of effects from chemicals in use but for which no data are available.

6.6 Risk Analysis and Criteria for Risk Characterization Categories

The final step in this risk analysis is the assignment of properties in the USSC lands to categories meant to assist the District in assessing the feasibility of using the USSC land for the WRPs envisioned in CERP. The previous subsections were used to support the development of criteria on which to base the categorization of the properties.

Once criteria were developed, properties within the site were assigned to Category 1, 2, or 3 using the data discussed in the geospatial analysis (Section 6.1.1). For purposes of supporting the District's purchasing decisions, these assessment categories were assigned to individual tracts of approximately 400 acres, the size of 10 contiguous individual sugarcane "fields". This size does not necessarily correspond to ecologically relevant areas, but provides a reasonable spatial resolution to evaluate the cost and scope of corrective actions. In general, the larger the contiguous area of high COPEC concentrations (i.e., high risk), the greater the chances that a project is not feasible for a given tract of land. The categories each use types and severity of toxicological effects into the decision criteria to assist in evaluating the 'net benefit' that would result from building the WRPs.

The three categories were assigned based on the following general characteristics. Details of categorization criteria are presented separately for aquatic life (benthos) and wildlife in sections 6.6.1 and 6.6.2, respectively.

6.6.1 Aquatic Community Risk Categorization

Data from the geospatial statistical analysis (Appendix D) were compared to criteria below as the basis of the categorization process for the aquatic community receptor.

The ERA Protocol prescribes the use of SQAGs for direct comparison of chemical concentrations and of the average PEC-Quotient (PEC-Q) that is used to assess the potential for risk from exposure to multiple COPECs. The use of the average PEC-Q is supported and discussed in MacDonald et al. (2003) for use in determining the probability for toxicity of a sediment sample.

Based on the results of the site-specific toxicity testing (Section 6.1.1), the use of the SQAGs was modified for assignment of land to the three Categories. No toxicity was noted in any sample unless one or more COPEC had a concentration greater than 10 times its respective PEC value (Table 6.2-1). Additionally, significant toxicity was never observed on any sample unless the average PEC-Q was greater than 3. Based on these results, it appears that the high TOC in muck soils is likely inhibiting toxicity to aquatic invertebrates due to binding of COPECs in the sediments. This binding is not likely to be as great within sandy soils. As a result, sandy soils are treated separately in the categorization process.

For arsenic and copper, samples collected for toxicity assessment did not have concentrations equal to the PEC. Instead, toxicity data were collected at ranges up to several times the TEC benchmark. Since the data were not available to assess toxicity from arsenic or copper at 3 to 5 times the PEC, three times the TEC was used in place of 3 times the PEC for determining whether arsenic and copper should be placed in Category 1 or 2. Similarly, the PEC was used to determine if arsenic or copper should be placed in Category 2 or 3 in each block.

Barium concentrations were not included in the block categorization process. Barium concentrations were noted in nearly all muck soil samples at concentrations from 1.5 to 2.5 times the PEC. No toxicity was noted in any of the samples targeted at evaluating toxicity of barium (at 1.5 to 2 times the PEC) collocated with arsenic and copper (at 1 to 3 times the TEC). Therefore, barium is not expected to be toxic throughout its range of concentrations in muck soils.

Similarly, detected concentrations of atrazine and 2,4-D were not included in the block characterization process. Both of these COPECs are agricultural herbicides with either short half lives or low toxicity ratings. Although 2,4-D is rated as highly toxic to aquatic species, it has a very short half life averaging approximately 7 - 10 days (Extoxnet 1996a). Atrazine has a relatively long half life (60 – 100 days), but is only slightly toxic to aquatic invertebrates (Extoxnet 1996b). Both of these chemicals have only TEC-SQAGs and both are very conservative values derived from a Dutch study using an equilibrium partitioning calculation to calculate the SQAG (Stortelder et al. 1989).

Widespread detections of atrazine were observed (Figure 5.1-7) in the sugarcane fields across the property, with a maximum detected concentration equal to 743 ug/kg. Atrazine toxicity was targeted in a toxicity test sample (4403DH; Table 3.3-2) with average concentrations equal to 88 ug/kg or 294 times greater than the TEC. No toxicity was observed in that sample which had concentrations greater than the average concentration in all areas of sugarcane cultivation. Since atrazine is being considered as part of the District's BMP assessment and it is not expected to be toxic at average concentrations across the property, it is not expected to contribute greatly to potential risk on the properties provided that it is managed in accordance with the BMP recommendations.

Although 2,4-D is more toxic than atrazine, its short half-life likely precludes potentially elevated risk. No samples containing 2,4-D were analyzed in the toxicity testing conducted for this site, but 2,4-D is being evaluated as part of the District's BMP assessment. With an 8 day half life, 2,4-D can go through more than 45 half lives in a single year. The maximum detected concentration in the sugarcane fields was 168 ug/kg (Table 3.1-10). Using an 8 day half life, the maximum concentration would be expected to be reduced to below the highly conservative TEC SQAG (0.03 ug/kg) in 13 half lives or 104 days. Provided the BMP recommendations are followed for 2,4-D, no significant effects to the aquatic community receptor are expected.

As described in previous sections, the USSC property was too large to allow sampling of all individual 40-acre fields. Therefore, some 400-acre blocks contain too few data points to calculate reliable 95^{TH} UCL concentrations within most blocks, and many blocks contained only a single data point. In such cases, the individual sample data or maxima were used in categorization, rather than 95^{TH} UCLs. In cases where multiple samples were available within the block, the maximum detected concentration (or ½ of the highest detection limit where all samples were non-detects) was also considered. In blocks where the maximum concentration exceeded the benchmark values discussed above but where the average concentration was less than the benchmark, there is increased uncertainty in the conclusion due to either small numbers of samples or variability in the data. As a conservative measure, all blocks with maximum concentrations greater than the category benchmarks were placed within the higher category. The categorization of these blocks carries higher uncertainty than in those where the average concentration of COPECs is greater than the benchmarks. Additional evaluation of these blocks should be considered prior to completion of WRPs in those areas.

In muck soils, the following criteria were used to place each block into a category:

Criteria for inclusion as Category 1:

- Blocks in which the maximum concentrations of all COPECs is less than 3 times the corresponding PEC SQAG.
- All blocks containing COPECs at concentrations that result in an average PEC-Q ratio less than 1.

Criteria for inclusion as Category 2:

- All blocks that contain a maximum concentration of any COPEC that is greater than 3 times the PEC, but where all COPEC concentrations are less than 5 times the PEC.

- All blocks containing COPECs at concentrations that result in an average PEC-Q greater than 1, but less than 2.

Criteria for inclusion as Category 3:

- Blocks for which the maximum concentration for any COPEC is greater than 5 times the PEC.
- Blocks containing COPECs at concentrations that result in an average PEC-Q greater than 2.

This is a conservative approach that identifies areas where variability in the data could mask areas of high concentration within the block and is used in place of the 95th UCL.

In sandy soils, the following criteria were used to place each block into a category:

Criteria for inclusion as Category 1:

- Blocks in which the maximum concentration of all COPECs is less than the corresponding PEC SQAG.
- All blocks containing COPECs at concentrations that result in an average PEC-Q ratio less than 0.5.

Criteria for inclusion as Category 2:

- All blocks that contain a maximum concentration of any COPEC that is greater than the PEC, but where all COPEC concentrations are less than 3 times the PEC.
- All blocks containing COPECs at concentrations that result in an average PEC-Q greater than 0.5, but less than 1.

Criteria for inclusion as Category 3:

- Blocks for which the maximum concentration of any COPEC is greater than 3 times the PEC.
- Blocks containing COPECs at concentrations that result in an average PEC-Q greater than 1.

A large number of 5-acre discrete samples were collected within the citrus groves and analyzed for copper. These samples were used in place of the composite copper concentrations to calculate block values. Since the number of copper samples within each block in the citrus groves was adequate to calculate a reliable estimate of the 95th UCL of the mean concentration within the block, the 95th UCL was used in the same manner as the maximum concentration for all other COPECs in all other areas of the property.

The results of this categorization are provided in Figure 6.6-1 for the entire agricultural area. All green shaded block are designated as Category 1, yellow shaded blocks are designated as Category 2 and red shaded blocks are designated as Category 3. Blocks shaded with a hatched pattern are those that have higher uncertainty in the categorization due to potential variability in the data within the block.

All block geospatial data are provided in Appendix D. Average PEC-Q calculations using the average block concentration and maximum detected block concentrations are provided in Table 6.6-2.

6.6.2 Aquatic-Feeding Wildlife Risk Categorization

The 400-acre blocks discussed in the previous sections were also used to categorize potential risk to aquatic-feeding wildlife across the USSC property. RBCs calculated using both NOAEL and LOAEL TRVs were calculated in Section 4 for all receptors in each of the five TOC sub-populations.

Each block was, therefore, assigned to a TOC sub-population. In cases where the block was located in more than one sub-population area, the block was assigned to the sub-population that made up the largest area of the block.

Block average and maximum COPEC concentrations were then compared to the lowest NOAEL and LOAEL based RBCs for the assigned TOC sub-population. Each block was them placed into a risk category representative of potential risks to aquatic-feeding wildlife based on the following criteria:

Criteria for inclusion as Category 1

> Blocks in which the maximum concentration of all COPECs is less than the corresponding NOAEL RBC for growth and/or reproduction-based endpoints.

Criteria for inclusion as Category 2

> All blocks that contain a maximum concentration of any COPEC that is greater than NOAEL RBC, but where all COPEC concentrations are less than the LOAEL RBC for growth and reproduction endpoints.

Criteria for inclusion as Category 3

> Blocks for which the maximum concentration for any COPEC is greater than the LOAEL RBC for growth, reproduction or mortality endpoints

For the same reasons as described in the previous section, all blocks with maximum concentrations greater than the category benchmarks were placed within the higher category, including those with average COPEC concentrations less than the category benchmarks. The categorization of these blocks carries higher uncertainty than in those where the average concentration of COPECs is greater than the benchmarks. Additional evaluation of these blocks should be considered prior to completion of WRPs in those areas.

All block data are presented in Appendix D. The results of this categorization are provided in Figure 6.6-2 for the entire agricultural area. All green shaded blocks are designated as Category 1, yellow shaded blocks are designated as Category 2 and red shaded blocks are designated as Category 3. Blocks shaded with a hatched pattern are those that have higher uncertainty in the categorization due to potential variability in the data within the block.

7.0 CONCLUSIONS

This ERA was conducted to support the Phase I/II ESA being completed as part of a broad due diligence evaluation to support the possible purchase of the USSC by the District. The Phase I/II ESA portion of the evaluation was intended to provide information regarding potential issues related to environmental contamination on the USSC properties. The ERA supports the ESA by providing information regarding potential ecological risks from residual agrochemicals in the actively farmed areas of the site that make up the bulk of the total land being contemplated for purchase by the District.

The overall ESA is intended, in part, to help the District determine whether WRPs are adequately feasible within the offered lands to justify the purchase of the property, based on the relative levels of ecotoxicological risk and an assessment of the potential corrective actions that may be necessary to render the property suitable for aquatic habitat after flooding. The ERA portion of the ESA attempts to predict the level of exposure and potential ecotoxicological risk represented by residual agrochemicals, and categorizes the lands according to the level of risk and by extension, the level of corrective actions that may be needed to render the property suitable for WRP construction. These actions could include corrective actions to reduce chemical concentrations, further risk-based study, and/or consultation with other state and federal agencies to consider the net environmental benefit of planned WRPs.

To that end, the assessment is intended to provide the District with several pieces of data to be used in the due diligence evaluation and in future WRP construction activities on the property. The ERA:

- Identifies agricultural chemicals that are present in the soils that should be considered prior to construction of aquatic habitats.
- Provides a risk-based categorization of agricultural lands in the offer that can be used:
  a. To aid in the selection of WRP locations by identifying relative ecotoxicological risks among different parts of the offered lands; and
  b. As a basis for estimating relative corrective action costs that may be required to render the property suitable for WRPs.
- The results generated in this report can also be used to focus future risk assessment activities once project extents and designs are known. In areas where this ERA predicts risks to be low or high, the necessary level of future assessment may be minimal. In cases where potential risks are somewhat unclear due to limited soil data and/or the need for more expanded ERA data, additional risk assessment tasks may be useful in refining the areas requiring corrective actions.

7.1 Risk-Based Categorization

Predicted risks to future aquatic and semi-aquatic receptors that are expected to inhabit WRPs constructed on the USSC lands were provided in Section 6.6. While there is considerable overlap in the extent of areas designated as Category 2 and Category 3 for the aquatic community and aquatic-feeding wildlife receptors, that overlap is not complete. In some areas, potential risks and the relative categorization were different. For that reason, the assigned categories for both receptors were incorporated into a single representation of the potential risk for all ecological receptors. The combined categorization is provided in Figure 7.1-1.

Blocks were assigned to a category based on the worst case for either receptor. For example, if a block were designated as Category 2 for the aquatic community receptor and Category 3 for the aquatic-feeding wildlife receptors, the combined designation was assigned as Category 3 reflecting the more sensitive receptor. Only in cases where the block was designated as Category 1 for **both** receptors was the combined categorization designated Category 1.

This approach allows the potential risk and possible need for corrective actions within each block to be based on the most sensitive receptor for the suite of COPECs detected within that block.

As discussed in Section 6.1, because of the large size of the property, not all of the 400-acre blocks used in the categorization were directly sampled. Therefore, the results of the geospatial analysis (Section 6.1) were used to complete the categorization in the blocks containing no sample points. Estimated concentrations across the property for each of the primary COPECs are shown in Figures 7.1-2 through 7.1-6. The concentrations for these COPECs predicted in the unsampled blocks were reviewed using the benchmarks described in Section 6.6. If any of the COPECs had geospatially estimated concentrations exceeding the Category 2 or Category 3 benchmarks, that block was classified in the highest category in which COPEC concentrations fell. If all concentrations were predicted to be below benchmarks, the block was designated as Category 1. Partial blocks at the edges of the property were similarly evaluated and placed into risk-based categories.

The category designations for the entire property were also reviewed based on the results of the geospatial analysis. The block categorization showed good visual correlation with the soil concentrations estimated using the variogram and kriging analysis.

Based on these rules, categorization of the properties strictly into the three categories results in the following distribution:

- Category 1 – 100,734 acres
- Category 2 – 36,394 acres
- Category 3 – 48,929 acres

Blocks that had maximum detected concentrations greater than the category benchmarks but average concentrations less than the benchmarks were placed into the higher category. This is a conservative measure but it indicates uncertainty in the characterization of these blocks due to the variable nature of the data within the block. Additional evaluation of these blocks as well as those where COPEC concentrations were estimated using geospatial statistical techniques should be considered prior to completion of WRPs. Actual risks within these blocks may be higher or lower than predicted based on the variability observed in the data from the USSC lands.

7.2 Summary

- Arsenic, barium, copper, selenium, atrazine, chlordane, 2,4-D, 4,4'-DDD, 4.4'-DDE, 4,4'-DDT, dieldrin, endosulfan sulfate, endrin, endrin ketone, heptachlor epoxide, and toxaphene were identified as COPECs based on screening-level evaluation, for either the aquatic-community receptor or the aquatic-feeding wildlife receptor or both.
- Elevated concentrations of copper, selenium, 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, and toxaphene represented the greatest potential for risk to either receptor and were primary focus of the risk-based categorization. However, potential risks from all of the COPECs were considered.
- Advanced geospatial statistical analyses were conducted for all COPECs to determine the average and maximum concentrations within a grid of 400-acre blocks superimposed on the USSC properties. Additional variogram and kriging analyses were conducted for copper, selenium, 4,4'-DDD, 4,4'-DDE, 4,4'-DDT and toxaphene to estimate concentrations of these COPECs across the entire site and to approximate the extent of elevated concentrations of each chemical.
- Aquatic toxicity studies indicated that the high organic carbon content of the muck soils prevalent throughout much of the property has a mitigating effect on toxicity from agrochemicals found in those soils. Ecologically significant toxicity was only noted in samples that had one or more COPECs present at greater than 10 times the PEC SQAG benchmark. Additionally, no samples caused significant toxicity at average PEC-Q values less than approximately 5.
- Multiple lines-of-evidence were combined to assign the USSC properties into one of three risk-based categories for the District's use. The categories are intended to provide an estimate of the amount of corrective actions that may be necessary if WRPs are constructed on the USSC property. Where future ecological risks are expected to be low, corrective actions are expected to be minimal (Category 1). Where future ecological risks would be expected to be high based on elevated COPEC concentrations in the soil, corrective action costs will also be expected to be high (Category 3). There is also a significant portion of the site where some corrective actions are likely due to moderately elevated risk, but the extent of those actions cannot be reliably predicted (Category 2).

- Of the approximately 187,000 acres in the assessment, the following were identified for each category:
    i. Category 1 – 100,734 acres
    ii. Category 2 – 36,394 acres
    iii. Category 3 – 48,929 acres
- Categorization of lands in Category 2 and 3 does not preclude construction of WRPs as there may be options for successfully siting WRPs in these areas. The District may initiate corrective actions to reduce COPEC concentrations to acceptable levels. The District may also seek consultation with the USFWS and FDEP to consider the net benefit of WRP construction as related to potential effects from elevated COPEC concentrations.
- No project plans were reviewed in the completion of this assessment and it is intended to provide only general risk-based classification to support the District's due diligence evaluation. If the lands are purchased and once specific project plans become available, the results of this ERA should be reviewed and used to focus future assessment on each WRP project in order to gain regulatory approval. Future assessments should rely on the data and conclusions presented in this report but should be supplemented with additional data and assessment as appropriate.

8.0 REFERENCES

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