Institute for Environmental Solutions

761 Newport Street
Denver, Colorado
80220-5554 USA
303.388.5211
www.i4es.org
Solutions@i4es.org

Trees for Healthy Kids and Community

ENVIRONMENTAL ANALYSIS

Mitchell Final Report
Attachment C

May 2011

Amory Ledyard

Institute for Environmental Solutions

Denver, Colorado

Scientific solutions for a better environment

TABLE OF CONTENTS

I. INTRODUCTION

The goal of *Trees for Healthy Kids and Community* is to create lasting, replicable, positive change in environmental health at Mitchell Elementary School (Mitchell) in Golden, CO. Mitchell faces multiple environmental challenges due to its proximity to Colorado Highway 93.

Specific challenges identified at Mitchell include:

- Particulate and gaseous airborne pollutants from the highway
- Noise pollution from the highway
- Strong wind

The school lacks a physical barrier between the campus and Highway 93, leaving the campus fully exposed to air and noise pollution and wind from the north and northwest. Concerns about the potential impact on students' health and the environment prompted the school administration and Parent-Teacher Association (PTA) to seek a solution to these problems. In establishing a vegetative barrier between the Mitchell campus and Highway 93, the IES *Trees for Healthy Kids and Community* project addresses the school's environmental challenges while optimizing the environmental benefits provided by trees.

Important additional benefits include:

- Stormwater runoff quality and quantity control
- Water conservation optimization

IES, Mitchell, the PTA Grounds and Garden Committee, Jefferson County Schools, Confluent Design, and the City of Golden collaborated to implement cost-effective, integrated, long-term solutions to these challenges by combining strategic tree selection and planting with education and outreach.

II. PURPOSE

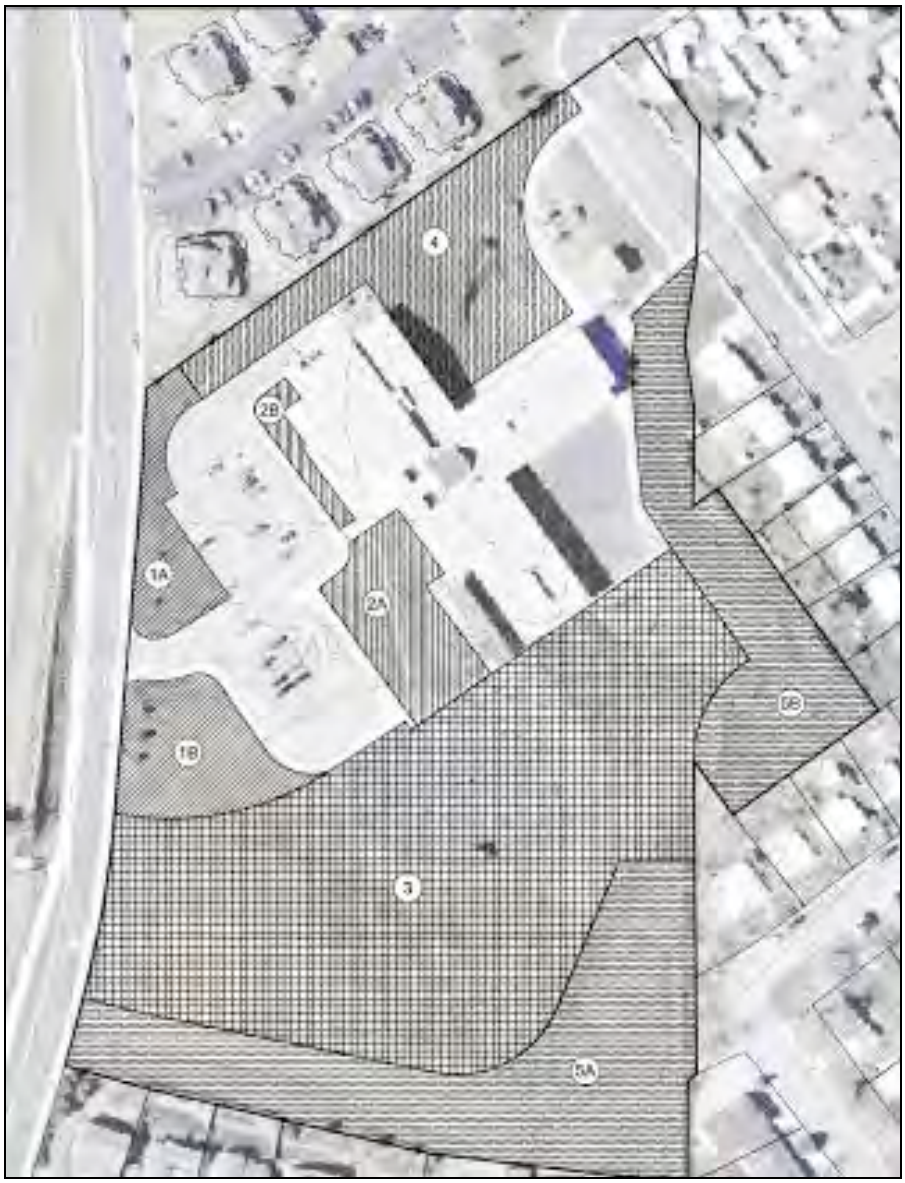
The purpose of this report is to assess indicators of environmental quality and evaluate the effectiveness of strategic tree selection and planting as a solution to improving environmental health at Mitchell. This analysis includes an evaluation of air quality, noise pollution, wind, stormwater volume and pollutant control, and water consumption.

III. SITE DESCRIPTION

Mitchell is located in Golden, Colorado in the Rocky Mountain Foothills west of Denver. The campus is on Rubey Drive between South Table Mountain and Highway 93. The school was constructed in 1998 and has little vegetative landscaping. Due to its proximity to Highway 93, Mitchell faces multiple environmental and health challenges.

The campus receives full, direct sunlight throughout the day and faces northern and northwestern winds. The soil mixture at Mitchell is moderately to severely compact and contains mostly clay and rock. Other soil considerations on the Mitchell campus include indications of soil layer disturbance, evidence of recent construction, presence of construction debris, and poor drainage. Figure 1 divides the Mitchell campus into landscape zones, each with categorical attributes that possess the potential to optimize additional tree function and benefits.

Figure 1. Mitchell Elementary Campus by Zone – Golden, CO, February 2011
Data Source: Kevin Lyles, Confluent Design



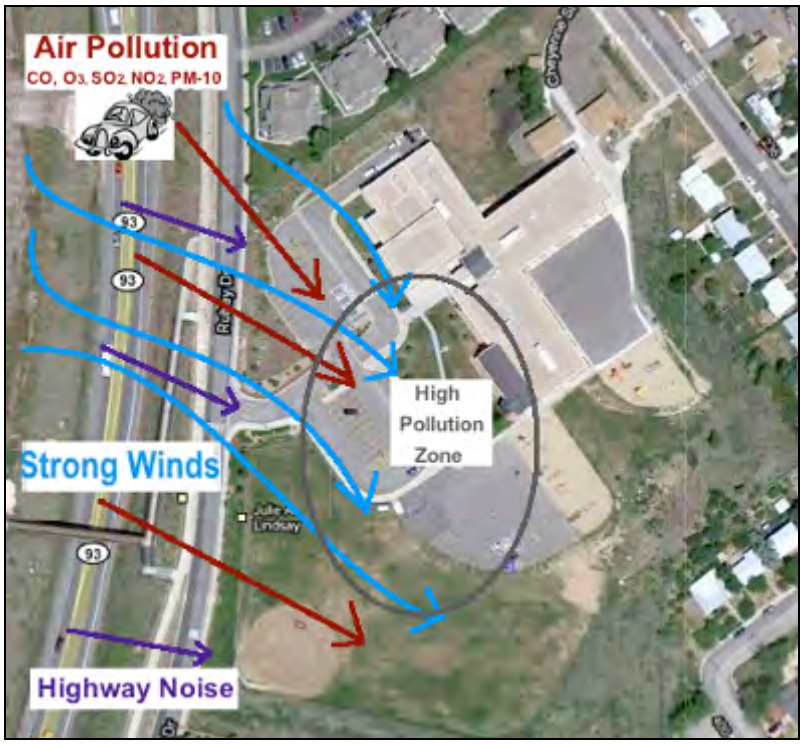
The existing landscaping of Zone 1A/1B, located along Rubey drive, includes turf shrubs and clustered evergreen trees. The grade of this landscape zone is moderate to flat, with eastern exposure. Zone 2A/2B, located in the center of the school's front parking lot, has irrigated landscaping with turf and scattered deciduous trees. The grade is nearly flat. Zone 3 is an active

play area for the school. This area encompasses a baseball field, two playgrounds, and turf grass. The grade of this zone ranges from flat to steep, with western exposure along Rubey Drive and northeastern exposure between the two playgrounds. This zone has very little vegetation aside from a few recently planted deciduous trees east of the upper playground. Zone 4 contains a detention basin north of the school, where stormwater runoff is collected and stored. A reinforced concrete pipe collects stormwater at the north end of the parking lot and directs it into the basin. Zone 5A/5B provides a landscape buffer between the active play areas and the surrounding residential development. The landscape grade is moderate to steep, with southern exposure in Zone 5A and eastern exposure in Zone 5B. Pasture grasses and some noxious weeds dominate this area. A few native trees and invasive plants are scattered throughout Zone 5A/5B (Lyles)[i].

IV. ENVIRONMENTAL IMPROVEMENT OBJECTIVES

The Mitchell community has long been concerned about the potential health impacts of gaseous and particulate air pollution, noise pollution, and wind, illustrated in Figure 2. Winds from the west and north carry particulate and gaseous air pollution from vehicular traffic on Highway 93 onto the Mitchell campus. Mitchell's main building blocks the natural flow of air over the ground surface, creating a pool where polluted air stagnates (Biggs)[ii]. The sounds of the wind and vehicles passing by on Highway 93 and Rubey Drive may cause uncomfortable and agitated conditions for children and adults who spend time in the outdoor recreation areas on campus.

Figure 2. Mitchell Environmental Concerns - Golden, CO, Spring 2011
Data Source: Institute for Environmental Solutions



A. GOAL: IMPROVE AIR QUALITY

Poor air quality is an on-going concern in the metro Denver region. Air pollution can cause damage to landscape and ecosystem processes and negatively impact human health. Health risks associated with air pollutants include: asthma, reduced lung function, lung damage, bronchitis, cancer, and brain and nervous system damage. Air pollution can be especially harmful to younger and older populations, particularly those individuals with pre-existing health conditions (EAP)[iii].

The Federal Clean Air Act of 1970 established the National Ambient Air Quality Standards (NAAQS), which identify and set regulations for specific criteria pollutants. Carbon monoxide (CO), ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and particulate matter (PM-10) are among these pollutants of concern (CDPHE)[iv]. In excess, each of these criteria pollutants can be detrimental to human health and the environment.

Table 1. The Federal Clean Air Act of 1970 National Air Quality Standards: Criteria Pollutants
Data Source: CDPHE, *Colorado Air Quality Data Report 2010*

CO: This colorless, odorless gas is formed when carbon in fuel is not burned completely. It is a component of motor vehicle exhaust, which contributes about 50 percent of all CO emissions nationwide. High concentrations of CO generally occur in areas with heavy traffic congestion. In cities, as much as 85 percent of all CO emissions may come from automobile exhaust. CO affects the central nervous system by depriving the body of oxygen. Health effects vary at different concentrations but include fatigue, chest pains, impaired vision, reduced brain function, headaches, dizziness, and confusion. At high concentrations, CO is deadly. Special concern exists for healthy young children because of increased oxygen requirements that result from a higher metabolic rate.
O_3: Depending on its location in the atmosphere, ozone can have either harmful or beneficial effects on human health and the environment. In the stratosphere, ozone creates a protective layer that blocks the sun's ultraviolet rays from harming life on Earth. Ground-level ozone (smog) is created by a chemical reaction between oxides of nitrogen (NO_x) and volatile organic compounds (VOCs) in the presence of sunlight. Motor vehicle exhaust, which emits both NO and VOCs, is a major source of ground-level ozone; however, trees may also contribute. Exposure to ground-level ozone can cause serious, long-term impairment of lung function. Active children are at the highest risk of ozone exposure because they often spend extended periods of time playing outdoors during summer months, when ozone production levels are highest.
SO_2: Sulfur dioxide gas is formed when fuel that contains sulfur (e.g. oil, coal, natural gas) is burned and when gasoline is extracted from oil. Sulfur dioxide dissolves in water vapor to form acid, and interacts with other gases and particles in the air to form sulfates and other products that can be harmful to people and their environment. High concentrations of sulfur dioxide can cause permanent lung damage, respiratory illness, and cardiovascular disease.

Asthmatic children and adults who are active outdoors are the most at risk.
NO_2: Nitrogen dioxide is formed when nitrogen and oxygen in the air are combined in high temperature combustion. In Denver, about 36 percent of NO_2 emissions come from motor vehicles. Elevated concentrations of NO_2 cause respiratory distress, degradation of vegetation, clothing, and visibility, and increased acid deposition. Nitrate aerosols, which result from nitric oxide and nitrogen dioxide combining with water vapor in the air, have been consistently linked to Denver's visibility problems.
Particulate Matter: Particulate pollution is a mixture of microscopic solid and liquid particles suspended in the air, such as dust, smoke, soils, organic chemicals, allergens, soot, and other microscopic particles. These small particles can enter the body and reach deep into the lungs and bloodstream, causing myriad health complications. The majority of particulate matter pollution comes from miscellaneous sources affected by earth-moving and wind-blown disturbances. A busy highway generates a significant amount of particulate pollution.

Air Quality at Mitchell

According to the Colorado Department of Transportation (CDOT) Traffic Information Report for Highway 93 in 2010, the annual average daily traffic count for vehicles passing Mitchell between mile reference point 0 (intersection of Route 6 and Clear Creek Canyon Road) and mile reference point 1.4 (intersection of Highway 93 and Golden Gate Canyon Road) was approximately 23,500 vehicles (CDOT)[v]. Accurate vehicle counts between these reference points are available on the CDOT webpage. This area is illustrated in Figure 3. Of the 23,500 vehicles passing by Mitchell daily, approximately 7.3 percent (1,715) were trucks. CDOT predicts that by 2020, the annual average daily traffic count for this location will increase to approximately 27,380 vehicles. Table 2 describes the average annual pollution emissions of carbon monoxide and nitrogen oxides by vehicles on Highway 93 between mile reference point 0 and 1.4. This is not a measurement of air quality at Mitchell but rather a measurement of source pollution. Emissions data for this 1.4-mile stretch contributes to total area emissions, for which there is not accurate data. Vehicles traveling on nearby roads and other sources will also contribute to total emissions impacting Mitchell.

The highway pollution emitted between mile reference point 0 and 1.4 may affect the environmental and human health conditions at Mitchell. Winds from the north and northwest carry pollutants from the highway to the school campus, creating a stagnant air pool in front of the main school building. This pool temporarily stores highway pollutants, making conditions in the parking lot and play areas potentially harmful to human health (Biggs)[ii].

Figure 3. Mile Reference Point 0 to Mile Reference Point 1.4, Highway 93, Golden, CO.

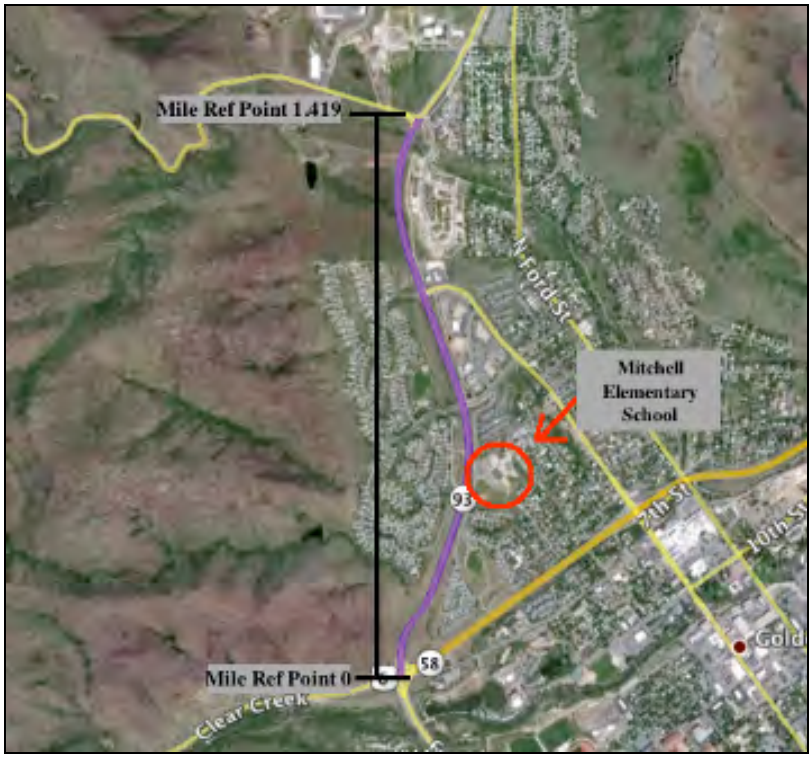


Table 2. Average Annual Pollution Emissions of CO and NO_x by Vehicles on Highway 93 Between Mile Reference Point 0 and 1.419, Golden, CO, 2010

Data Source: USEPA, *Emission Facts: Average Annual Emissions and Fuel Consumption for Passenger Cars and Light Trucks, 2000*. CDOT, *Vehicle Traffic Volumes and Truck Weights on Colorado State Highways,* 2010.

Pollutant	Annual Avg. Daily Traffic 2010	Emission Rate per (g/mi)	Calculation	Annual Pollution Emitted from H93 (0-1.419)
Passenger Cars				
CO	21,785 cars	20.9	(21,785 cars) x (1.4 mi x 20.9 g) x (365 days/year) x (1 lb/454 g)	**519,000 pounds of carbon monoxide**
NO_x	21,785 cars	1.39	(21,785 cars) x (1.4 mi x 1.39g) x (365 days/year) x (1 lb/454 g)	**34,500 pounds of oxides of nitrogen**
Light Trucks				
CO	1,715 trucks	27.7	(1, 715 trucks) x (1.4 mi x 27.7 g) x (365 days/year) x (1 lb/454 g)	**54,200 pounds of carbon monoxide**
NO_x	1,715 trucks	1.81	(1, 715 trucks) x (1.4 mi x 1.81 g) x (365 days/year) x (1 lb/454 g)	**3,650 pounds of oxides of nitrogen**

The emission rates displayed in Table 2 are averages for the entire in-use fleet determined in April 2000. Newer cars and trucks will emit less pollution and use less gasoline; older cars and trucks may emit more pollution and use more gasoline. The emission rates assume an average, properly maintained vehicle on the road in July 2000, operating on typical gasoline on a warm summer day (72-96 degrees F). Emissions may be higher in very hot or very cold weather. (USEPA).[vi] While not listed in Table 2, ground-level ozone, sulfur dioxide, and particulate matter from vehicles on Highway 93 also negatively impact Mitchell's local environment, see Table 1.

Impact of Urban Trees on Air Quality

Trees improve air quality by directly removing particulate pollutants from the air by intercepting them on leaf surfaces and by absorbing gaseous pollutants (O_3, CO, SO_2, and NO_2) during photosynthesis through the leaf stomata (Nowak)[vii]. When properly cared for and maintained, trees have the ability to improve air quality by:

- Moderating air temperatures
- Increasing oxygen levels
- Intercepting and trapping particulate matter air pollution
- Absorbing gaseous pollutants
- Binding or absorbing water-soluble pollutants on leaf surfaces

(*The IES Tree Project Phase 2 Final Report*)

Trees may also be a detriment to air quality through the emission of VOCs, which can contribute to ground-level ozone formation when combined with sunlight and NO_x. Strategic tree selection and planting is crucial to optimizing the impact of trees on air quality, since VOC production and ozone absorption varies significantly by species (*The IES Tree Project Phase 2 Final Report*).

Using Trees to Improve Air Quality at Mitchell

Trees can serve as a physical buffer between pollution sources, such as highways, and places where people work and play. This essential function of trees is especially relevant at Mitchell, considering the lack of any physical barrier between the school and Highway 93. Proper placement of trees is fundamental to improving air quality at Mitchell. Certain tree species planted as barriers along roadways and parking lots can be particularly effective at reducing particulate and gaseous airborne pollution. In addition, trees can efficiently serve as filters to street debris and other pollutant emissions. For more detailed information on the ways in which trees can improve air quality, please consult *The IES Tree Project Phase 2 Final Report*.

IES has identified several strategies to improve air quality at Mitchell with urban forestry:

- Increase the number of healthy, large, and long-lived tree species. This will help increase pollution removal and optimize the positive effect of each tree.
- Sustain the existing tree cover to help maintain pollution removal levels.

- Plant low-maintenance trees to minimize pollution emissions from maintenance activities.
- Plant trees to shade parked cars and reduce vehicular VOC emissions.
- Select tree species that will best optimize environmental improvement objectives. At Mitchell, including evergreen trees in the mix will provide year-round removal of particulate matter.

(*IES City of Golden Strategic Tree Planting Plan for Environmental Improvement)*

B. GOAL: REDUCE NOISE POLLUTION

Noise pollution is defined as unwanted or disturbing sound that interferes with normal activities (USEPA)[viii]. Studies show that there are direct links between noise and health. Excessive noise can have adverse effects on the physical and psychological health of children, which is related to learning and behavior. According to the EPA, noise can pose a serious threat to a child's physical and psychological health, including learning and behavior. For example, noise can interfere with speech and language, and impair learning and hearing. Other problems associated with excessive noise include increased stress levels, high blood pressure, hearing loss, and lost productivity.

Noise is measured by the intensity and frequency of sound waves that hit the ear. Volume of sound is measured in decibels (dB). The greater the number of decibels, the louder the noise and the more harmful it is to hearing ability. In schools the critical effects of noise are speech interference, disturbance of information extraction, message communication, and annoyance. For outdoor playgrounds the sound level of the noise from external sources should not exceed 55 dB (WHO)[ix]. Noise levels above 85 dB, such as the sounds of busy traffic, can be hazardous to human health (USEPA)[viii]. The 55 dB recommendation is based less on safety and more on comfort, reduced stress, less annoyance due to noise, and less effort needed to listen and understand what is happening in the environment. During a child's developmental stages, it is important to keep noise at a comfortable level, less than 55 dB.

Noise Pollution at Mitchell

Noise pollution occurring from Highway 93 and Rubey Drive pose comfort and health concerns for students at Mitchell. IES conducted a noise evaluation of Mitchell's front outdoor playground. The purpose of this noise evaluation was to characterize noise conditions and establish baseline measurements for future efforts to quantify the environmental impacts of the *IES Trees for Healthy Kids and Community* project. Noise readings were taken in April and May 2011 at varying 15-minute intervals throughout the day, see Table 3. Readings were taken with a Quest Electronic M-27 Noise Logging Dosimeter, provided by Bethany Messersmith of CoorsTek, Inc.

Table 3. Noise (dB) Readings, Mitchell Elementary, April – May 2011, Golden, CO

Date and Time	Environment	Max dB	Average dB
4/27 10:30-10:45 a.m.	Mitchell	84.3	56.0
4/27 2:35-2:50 p.m.	Mitchell	87.9	63.2
4/27 5:00-5:15 p.m.	Mitchell	106.6	60.9
5/11 10:30-10:45 a.m.	Mitchell	74.2	54.4
5/11 2:30-2:45 p.m.	Mitchell	92.8	63.5
5/11 5:00-5:15 p.m.	Mitchell	88.6	59.4
5/18 9:35-9:50 a.m.	Mitchell	78.6	52.2
5/18 12:15-12:30 p.m.	Mitchell	79.5	54.5
5/18 5:00-5:15 p.m.	Mitchell	92.7	61.1
5/25 9:05-9:20 a.m.	Mitchell	72.0	54.9
5/25 2:10-2:25 p.m.	Mitchell	90.1	58.0
5/25 4:45-5:00 p.m.	Mitchell	93.7	55.5

While average noise readings did not reach the dangerous levels that could cause permanent hearing and/or health damage, the average readings remained above the WHO's recommendation of 55 dB for outdoor playgrounds. Cars, garbage trucks, and school buses passing along Rubey Drive as well as occasional wind gusts contributed most to the high noise level readings. The highest noise level reading was recorded at 106.6 dB, which is equivalent to the noise produced by a chainsaw or a rock concert. Instantaneous exposure to high noise levels, such as 105 dB and above, is considered hazardous could cause permanent hearing damage (CDC)[x].

Using Trees to Reduce Noise Pollution at Mitchell

Vegetative noise buffers composed of strategically selected tree species can reduce noise by approximately five to ten decibels. This decrease could reduce noise by up to 50 percent to the human ear (USDA National Agroforestry Center)[xi]. The USDA National Agroforestry Center has researched and published comprehensive guidelines for using trees as noise buffers. USDA-NAC recommendations include:

- Use plants with dense foliage. A diversity of tree species, with a variety of foliage shapes and sizes within the noise buffer may also improve noise reduction.
- Foliage of the plants should persist from the ground up. A combination of shrubs and trees may be necessary to achieve this effect.
- Evergreen varieties that retain their foliage will give better year-round protection.
- Use taller trees.
- Plant trees and shrubs as close together as the species will allow.
- Plant the noise buffer close to the noise source, rather than close to the area being protected.
- The length of the tree belt should be twice as long as the distance from the road to the recipient of the noise.
- The buffer should extend equal distance in both directions parallel to the road.

(USDA National Agroforestry Center)[xi]

C. GOAL: REDUCE IMPACT OF WIND

Wind, at varying speeds, can cause a number of environmental issues, including carrying airborne pollutants far from the source, contributing to noise pollution, causing environmental disturbances, and creating a stressful atmosphere.

Wind at Mitchell

Wind is the natural horizontal motion of the atmosphere. It occurs when warm air rises, and cool air comes in to take its place. Wind disperses and transports pollutants from the source to areas that may not otherwise have been affected (USEPA)[xii]. IES and the Mitchell community identified winds prevailing from the north and west as a contributor to air pollution and noise on campus. Table 4 provides average wind speed and temperature data taken from a home weather station located in residential neighborhood on the western side of Highway 93 from Mitchell. While this data is not necessarily representative of actual conditions on the Mitchell campus, it provides a general indication of weather conditions in the area.

Table 4. Wind Speed and Temperature Data, Near Mitchell Elementary, Golden, CO
Data Source: Mt. Ridge. Foothills West of Golden, Golden, CO Weather Station

Month / Year	Average Wind Speed (mph)	Max Wind Speed (mph)	Average Temperature (° F)
JAN 2010	1.2	46.0	33.9
FEB 2010	1.1	45.0	29.3
MAR 2010	2.5	43.0	40.8
APR 2010	2.6	50.0	47.0
MAY 2010	2.8	57.0	52.8
JUN 2010	2.3	36.0	68.5
JUL 2010	2.4	38.0	72.1
AUG 2010	2.6	34.0	71.7
SEP 2010	2.0	32.0	66.6
OCT 2010	2.4	57.0	54.4
NOV 2010	1.4	45.0	40.8
DEC 2010	1.5	65.0	38.7

Using Trees to Reduce Wind at Mitchell

Properly selected and positioned tree species can reduce the impact of wind and moderate air and ground temperatures. When strategically planted, trees have the ability to act as a windbreak, shade surfaces, and conserve energy.

IES identified strategies that will optimize shade and reduce the impact of wind:

- Plant evergreens on the northern / western edge of the area being protected to provide summer shade and winter wind protection.

- Increase canopy cover to reduce ambient air temperature.
- Use large, full, evergreen trees to create a year-round windbreak.
- Select and plant trees that provide wind relief and may also reduce noise pollution.

(*IES City of Golden Strategic Tree Planting Plan for Environmental Improvement)*

D. GOAL: IMPROVE STORMWATER MANAGEMENT

Stormwater runoff occurs when precipitation does not permeate into the ground. As stormwater flows over the ground surface, it accumulates debris, chemicals, and other pollutants that could contaminate water quality if not properly treated (USEPA)[xiii]. Unlike wastewater and sewage, stormwater is not treated before entering waterways and areas of human contact. Adequate stormwater management and control is essential to providing a healthy and safe environment.

Using Urban Trees to Improve Stormwater Management at Mitchell

Strategically planted trees can function as a natural stormwater management tool by slowing the flow and decreasing the volume of runoff and reducing the pollutant load as stormwater percolates into the ground. A typical medium-sized tree can intercept as much as 2,300 gallons of rainfall per year. Trees that are in-leaf year round have the capacity to intercept the most rainfall and provide the most environmental and health benefits. Broadleaf evergreens and conifers intercept more rainfall than deciduous species where winter rainfall patterns prevail (USDA Forest Service)[xiv]. IES has researched ways in which strategic tree selection and planting can improve stormwater pollutant control. Specific strategies include:

- Choose species that are in-leaf when precipitation is greatest for the region.
- Select species with architectural features that maximize interception, such as large leaf surface area and rough surfaces that store water (e.g. conifers intercept more precipitation than similarly sized deciduous trees).
- Increase tree canopy and improve maintenance of existing trees.

(*IES City of Golden Strategic Tree Planting Plan for Environmental Improvement)*

At Mitchell, the ground consists of mostly compact clay and rock and exhibits poor drainage abilities. A reinforced concrete pipe at the north end of the parking lot collects stormwater from the school building and parking lot and directs it into a detention basin north of the school in Zone 4, where it is temporarily stored, see Figure 1. Planting trees along the northern fence line of campus would contribute greatly to Mitchell's stormwater management practices. While stormwater flow and pollutant control isn't one of the top environmental priorities of Mitchell, it is an additional benefit of properly selected and placed trees that will help reduce costs and keep a clean environment in the long run.

E. GOAL: OPTIMIZE WATER CONSERVATION

Colorado's Front Range has a semi-arid and dry climate. Water-use efficiency and conservation is critical in the urban Front Range community, where access to water resources is limited. Water conservation efforts are important in meeting long-term water supply needs, sustaining environmental health, and maintaining quality of life standards (CWCB)[xv].

Using Urban Trees to Conserve Water at Mitchell

The soil composition at Mitchell consists mostly of clay and rock and has poor drainage abilities. Selecting native, drought-resistant trees accustomed to Colorado's climate is very important for the long-term health and survival of trees planted at Mitchell. In a place where access to water is limited, planting species with low water consumption requirements is essential.

IES has identified several strategies that can help improve water conservation:

- Plant drought-tolerant or xeric trees.
- Use water-saving, efficient irrigation methods.
- Water in the evenings or early morning. Do not over-water.
- Maximize energy-saving benefit of trees to reduce power plant water consumption

(*IES City of Golden Strategic Tree Planting Plan for Environmental Improvement)*

V. MITCHELL PLANTING PLAN

IES, in collaboration with the City of Golden Forester Dave High, and Landscape Architect Kevin Lyles, researched and developed a comprehensive, strategic landscape plan that will support Mitchell in reaching its environmental improvement objectives.

Phase One – Mitchell Planting Plan

The Phase One landscaping approach for Zone 1A/1B is based on observed environmental improvement targets and on strategic landscape design practices that will maximize environmental benefits. The landscape design focuses on using strategic tree selection and placement along the school's northern and western fence lines to create a vegetative buffer between Highway 93 and Mitchell Elementary, see Figure 4. The tree buffer will:

- Mitigate highway air pollution on the school campus by absorbing and intercepting pollutants *and* disrupting and diverting the natural airflow.
- Reduce highway noise pollution by absorbing sound waves.
- Create a calm and controlled environment by diverting winds prevailing from the north and west.
- Contribute to on-site stormwater management by intercepting and slowing the flow of precipitation.
- Conserve water by selecting native, drought-tolerant species.

Tree species were carefully and strategically selected to optimize environmental benefits and to minimize potential negative impacts, such as increased air pollution. Similarly, planting locations of each species have been designated to best meet the environmental needs of the school. A mix of conifer and evergreen varieties along with a few select deciduous trees will create a vegetative barrier, offering the Mitchell campus year-round protection from wind, air pollution, and noise. IES predicts that as the trees mature to form a full vegetative buffer, the average wind speed, air pollution levels, and noise on the Mitchell campus will decrease. The mix of conifers and evergreens will contribute to slowing the volume and flow of precipitation by intercepting rainfall year-round. The planting plan only includes drought-tolerant species that will maximize water conservation benefits.

Long-term Mitchell Planting Plan

The remaining landscape zones offer opportunities for tree planting and vegetative management, outdoor learning areas, and additional environmental improvement. Figure 5 illustrates the proposed long-term strategic landscape plan for Mitchell.

The long-term landscape design recommends increased tree canopy and shade in the parking lot. The intention in area encompassing the ball field is to provide shade and create a secondary wind buffer for the upper and lower playgrounds. The design purpose in the area north of the school building is to improve water quality and stormwater management by creating a vegetative swale that supports native plants. This area also provides an opportunity to transform the stormwater detention basin into a wetland educational area that could support a native riparian plant community. The southeast corner of campus will focus on enhancing the ecological integrity of the existing native plant community by creating a prairie learning area. The completion of the long-term landscape design is contingent on future interest by the Mitchell community and availability of funding.

VI. CONCLUSION

As part of the *Trees for Healthy Kids and Community* project objective to achieve lasting, replicable, positive change at Mitchell, IES and the Mitchell Project Committee plan to monitor the environmental benefits of the trees as they mature. A tree maintenance plan has been instituted and will help ensure the long-term survival and health of the trees. The Phase One planting plan allows the Mitchell community to reach its environmental improvement objectives through strategic tree selection and management.

Figure 4. Mitchell Elementary Planting Plan and Tree Species Selection– May 1, 2011
Data Source: Kevin Lyles, Confluent Design

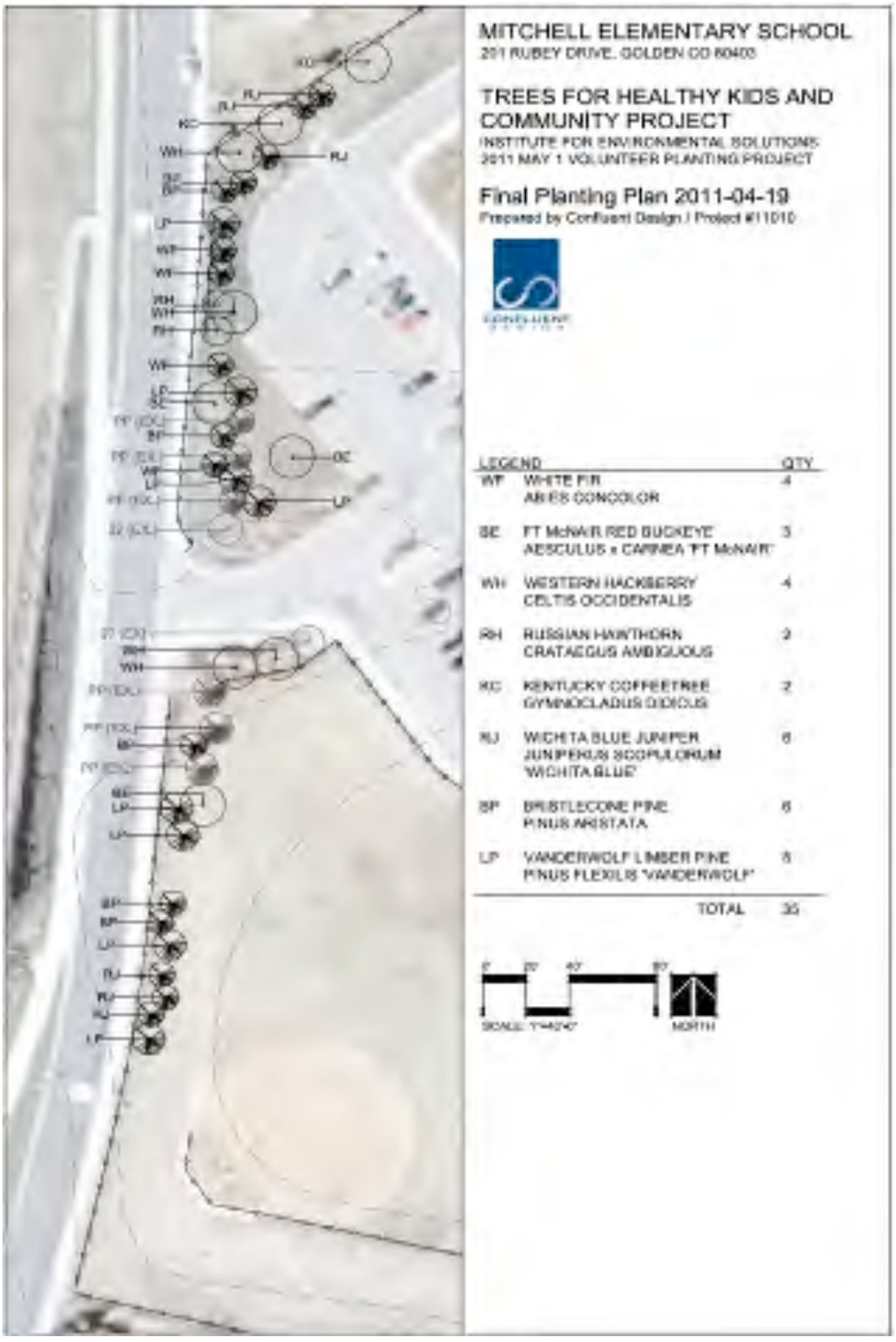


Figure 5. Long-term Landscape Design Concept for Mitchell Elementary – Golden, CO
Data Source: Kevin Lyles, Confluent Design

References

[i] Lyles, Kevin. (Landscape Architect) "Mitchell Elementary Campus Description by Zone." Confluent Design.

[ii] Biggs, Gale W., Ph.D., W. Gale Biggs Associates. (Air Quality Meteorologist) "Air Quality Evaluation of Mitchell Elementary Campus." IES Tree Project - *Trees for Healthy Kids and Community*. Mitchell Elementary School, Golden, CO. 3 March 2011. Lecture.

[iii] Environmental Assessment and Policy (EAP) Section, "The Importance of Air Quality." *City and County of Denver Official Site*. City and County of Denver, 9 June 2011. < http:// www .denvergov.org / OutdoorAirQuality/ TheImportanceofAirQuality/ tabid/ 424909/ Default.aspx>.

[iv] Colorado Department of Public Health and Environment (CDPHE), Air Pollution Control Division. *Colorado Air Quality Data Report 2010*. Denver: 2010. Web. <http://www.colorado.gov/airquality/tech.asp&xgt;.

[v] Colorado Department of Transportation (CDOT). *Vehicle Traffic Volumes and Truck Weights on Colorado State Highways*. 2010. Web. <http://apps.coloradodot.info/dataaccess/Traffic/index.cfm?fuseaction=TrafficMain>.

[vi] United States. Environmental Protection Agency (USEPA). *Emission Facts: Average Annual Emissions and Fuel Consumption for Passenger Cars and Light Trucks*. USEPA, 2000. Web. <http://www.epa.gov/otaq/consumer/f00013.htm>.

[vii] Nowak, D. USDA Forest Service. *Effects of Urban Trees on Air Quality*. Syracuse: Web. <http://www.fs.fed.us/ne/syracuse/gif/trees.pdf>.

[viii] United States Environmental Protection Agency (USEPA), Office of Air and Radiation. *Noise and Its Effects on Children*. Washington D.C., 2009. Web. <www.epa.gov/air/noise.html>.

[ix] World Health Organization (WHO). *Guidelines for Community Noise*. London: , 1999. Print.

[x] Centers for Disease Control and Prevention (CDC). *Noise-Induced Hearing Loss Signs - Adolescent and School Health*. Atlanta: , 2011. Web. <http://www.cdc.gov/healthyyouth/noise/signs.htm>.

[xi] USDA National Agroforestry Center. "Trees as Noise Buffers." *Overstory Agroforestry eJournal*. 60. n. page. Web. 28 Nov. 2011.

[xii] United States Environmental Protection Agency (USEPA), *Transport & Dispersion of Air Pollutants*. USEPA, 2010. Web. 28 Nov 2011. <http://www.epa.gov/apti/course422/ce1.html>.

[xiii] United States Environmental Protection Agency (USEPA), . "EPA Stormwater Program." . USEPA, 12 Jan 2011. Web. 08 June 2011. <http://cfpub.epa.gov/npdes/home.cfm?program_ id=6>.

[xiv] USDA Forest Service. Center for Urban Forest Research. *Is all your rain going down the drain?* Urban Forest Research, July 2002. Print.

[xv] Colorado Water Conservation Board (CWCB), . Colorado Department of Natural Resources. *Water Conservation*. Web. <http://cwcb.state.co.us/water-management/conservation/Pages/main.asp&xgt;.

FOR MORE INFORMATION PLEASE CONTACT:
Institute for Environmental Solutions
761 Newport Street
Denver, CO 80220-5554
www.I4ES.org, Solutions@i4es.org