BIODIVERSITY DESIGN GUIDELINES

LIGHT ABATEMENT

2

Context

Lighting is an integral feature of human settlements and can be important for safety, security, and productivity; however, artificial light also comes with a cost. Artificial light has been shown to have negative effects on mammals, birds, amphibians, fish, invertebrates, and plants.[1,2] Furthermore, light pollution is increasing faster than the rate of human population growth[3], which is having profound effects on biodiversity and habitat quality within cityscapes.

Artificial light effectively turns night into day, which has significant health and behavioural implications. These effects are significant when the level of artificial light is comparable to a full moon, but are also apparent at lower brightness.[4] Artificial lighting can disrupt the circadian rhythm (i.e., the natural sleep-wake pattern) of animals, plants, and people.[5] Wildlife, particularly nocturnal species, may react to light by changing their travel patterns, feeding, reproduction, or migratory behaviour, which can increase mortality risk. For example, birds that migrate at night can become disoriented by lit buildings and fly into them. Collisions with buildings and structures is estimated to be the second leading cause of human-induced mortality for birds.[6]

Well-designed lighting considers energy efficiency, and the precise locations, types, amounts, and timing of light needed. While well-designed lighting can minimize the negative impacts of light on living organisms, it is important to understand that humans perceive light differently than other species. Depending on the species, wildlife can be sensitive to different wavelengths on the ultraviolet (UV), infrared (IR), and visible light spectrums.[2] Therefore, additional lighting considerations are required when designing for biodiversity. Effective lighting can be achieved by following Best Practices in lighting design, which are outlined in this module.

Surrey City Hall
Credit: City of Surrey

Key Considerations:

- ☑ Turn off or mask interior lights visible to the outside at night, especially during wildlife migration and foraging periods (e.g., spring through fall for many species such as birds, insects, and bats).
- ☑ Implement a municipal "Lights Out" program that applies throughout the year (e.g., Dark-Sky Protection Program, Fatal Light Awareness Program).
- ☑ Start with natural darkness and only add light for specific purposes. Lighting should only be used in appropriate/required locations and only for as long as needed.
- ☑ More light is not necessarily better, and care must be taken to ensure that the light levels are right for the circumstances and commensurate with the risk and fear of crime. Lighting is a key design element used to modify the environment as part of Crime Prevention Through Environmental Design (CPTED) initiatives. Use the lowest intensity lighting feasible to meet illumination needs for safety and security.
- ☑ Use adaptive light controls and smart technology to manage light timing, intensity, and colour.
- ☑ Light only the object or area intended. Keep lights close to the ground, directed, and shielded to avoid spillover.
- ☑ Use non-reflective, dark-coloured surfaces to reduce amount of reflected light contributing to skyglow (light pollution). Buildings and walls painted white or shiny surfaces can reflect light and contribute to skyglow.
- ☑ Wildlife are more sensitive to shortwave blue/violet and ultraviolet light. These wavelengths are between 400-500 nanometers (nm) on the electromagnetic spectrum. Short wavelength light scatters more than long wavelength light and contributes more to skyglow.
- ☑ Consider use of vegetative screens (e.g., trees and shrubs) and wildlife tunnels to shield habitat for light-sensitive wildlife.

DID YOU KNOW?

The amount of light a building emits, rather than its height, is a greater predictor of bird-related mortality. Reducing the amount of exterior lighting can reduce bird-collisions and mortality, but results are significantly better if this strategy is implemented across a wider area. Municipal "Lights Out Programs" that encourage business owners and residents to reduce nighttime lighting during spring and fall migration are a great way to help support bird biodiversity. These programs also improve building efficiency, increase energy savings, and reduce greenhouse gas emissions, along with many other benefits.

Relevant Surrey Documents:

- ☑ Biodiversity Conservation Strategy (2014)
- ☑ Official Community Plan (2013)
- ☑ Climate Adaptation Strategy (2013)
- ☑ Community Climate Action Strategy (2014)
- ☑ Literature Review of Potential Effects on Wildlife – City of Surrey LED Streetlight Conversion Program (2016)
- ☑ Park Design Guidelines (2020)
- ☑ Engineering Department Design Criteria Manual (2020)

ICON LEGEND:

Mammals

Birds

Herptiles

Fish

Plants

Invertebrates

Cost Legend: Relative Cost: $ (low), $$ (medium), and $$$ (high).

Module linkages:

2.1 BIRD FRIENDLY LIGHTING

Overview

Collisions with buildings and towers kill hundreds of millions of birds in North America every year. While a majority of these collisions are attributed to reflective glass that birds confuse with habitat, artificial lighting exacerbates the problem. Most birds are active by day; however, birds may be attracted to artificial light sources during nocturnal migration (light is thought to act as a horizon cue). Birds also navigate at night using magnetic fields; red wavelengths present in much of our artificial lighting can disrupt this magnetic sense and disorient birds. Buildings that emit a lot of light may attract more birds during migration periods, which can increase the risk of collision and mortality in urban areas.[9]

Artificial light sources can also cause disorientation as birds alter flight paths and circle lit structures repeatedly, which increases the risk of collision with objects including other birds. This phenomenon is more common with telecommunication towers rather than buildings.

Artificial light from towers may be particularly attractive to nocturnal migrants during periods of poor visibility caused by low cloud cover, fog, or other adverse weather. Once birds are "captured" by this artificial light, they may be reluctant or unable to disperse. Studies have shown that birds resume normal migration when these lights are temporarily turned off.[10]

The type of light also matters. Studies looking at patterns of collision risks with towers have showed that more bird-collision mortalities have been linked to towers with steady, non-flashing, red lights than towers with only white, flashing strobes.[11]

A - Exterior sheilded lighting - User controls direction, intensity and duration of lighting - Credit: Selux
B - Robert H. Lee Alumni Building - Credit: Nic Lehoux
Architects: KPMB Architects in joint venture with HCMA Architecture + Design

Fatal Light Awareness Program (FLAP)

The Fatal Light Awareness Program of Canada (FLAP) has developed nationally recognized BirdSafe Building recommendations for interior and exterior lighting:[12,13]

Interior Lighting:

- ☑ Turn off all lights in unused interior spaces.
- ☑ Draw blinds when interior spaces are occupied.
- ☑ Turn off non-security overhead lighting in occupied spaces.
- ☑ Encourage the use of task lighting at work stations.
- ☑ Isolate lighting for human safety and building security to areas as the law and code requires.
- ☑ Switch to cleaning of interior spaces during daylight hours where feasible.
- ☑ Dim lights from 11pm to 6am in public areas (i.e., lobbies, atria, retail, etc.).
- ☑ Install motion sensors or an auto shutoff system with a maximum 30-minute vacant period.

Exterior Lighting:

- ☑ Install only shielded, downward directed fixtures.
- ☑ Limit exterior architectural lighting fixtures to grade level.
- ☑ Limit lighting to areas where required for safety and security.
- ☑ Prohibit spot, flood, and advertising lighting during bird migration months: March through May and August through October.

FURTHER READING:

Bird-Safe Standard for Federal Government Buildings - A Synthesis of Bird-Friendly Guidelines and Standards.[13]
Bird-Friendly Building Design.[8]
International Dark Sky Association.[1]
Canadian Guidelines for Outdoor Lighting (Low-Impact Lighting) for RASC Dark-Sky Protection Programs.[4]

A - Glass building facade example - Credit: Wikicommons
B - Bird Friendly Design Example - UBC CIRS Building - Credit: Daniela Orbegoso Campbell

2.2.1 NATURAL DARKNESS

Lighting should be sensitive to the surrounding environment, particularly in areas such as natural areas and urban forests. Allow for areas of natural darkness where lighting is prohibited.[4] These "Naturally Dark Zones" can be coordinated with important wildlife areas, or in areas where the City would like to minimize disturbance to wildlife. Lighting can also be attenuated at certain times of the year to coincide with sensitive life-history stages (e.g., breeding or migration periods).

Design Guidelines:

- ☑ Consider designating "dark places" where outdoor lighting is prohibited.
- ☑ Minimize light intrusion into parks and natural areas from adjacent residences, businesses, and streets.[14]
- ☑ Limit light in parking lots, buildings, and signage to what is necessary.
- ☑ Avoid use of white light LEDs with blue light components and Metal Halide (MH) lamps. Lights with high blue spectral content and UV can affect wildlife sensitive to those wavelengths.[4]
- ☑ Use amber spectrum bulbs instead of blue light in natural areas where use of lighting cannot be avoided.

Focal Guilds and Species: All.

Where to implement: Ecologically sensitive areas (e.g., wetlands, fish spawning areas, bird migration routes, areas with high bat activity).

What to Watch For: Allowing natural darkness may not be possible in some areas requiring light for safety.

2.2.2 INTENSITY AND SPECTRUM

Intense lighting interrupt normal sleep cycles and inhibit or alter nocturnal hunting and foraging behaviour of fauna in the air, on the ground, and in the water. Infiltration and penetration of light into vegetation, ground cover, and water/aquatic habitat, has had documented impacts on insects, terrestrial vertebrates, semi-aquatic mammals, amphibians, and fish.

Understanding how animals perceive light is important to develop effective biodiversity-focused lighting. Other species do not see colour the same way humans do, due to differences in the retina. Depending on the species, animals see visible light from 300nm to greater than 700nm on the electromagnetic spectrum. The part of the spectrum visible to the human eye is between 380nm – 780nm.[7] While most animals will see a more restricted range of colour, some animals can detect other spectrums of light (e.g., infra-red for some snakes and ultraviolet for birds and insects) that humans cannot. The wavelengths that a particular species perceives (or is sensitive to) will inform the type of lighting that should be designed for.

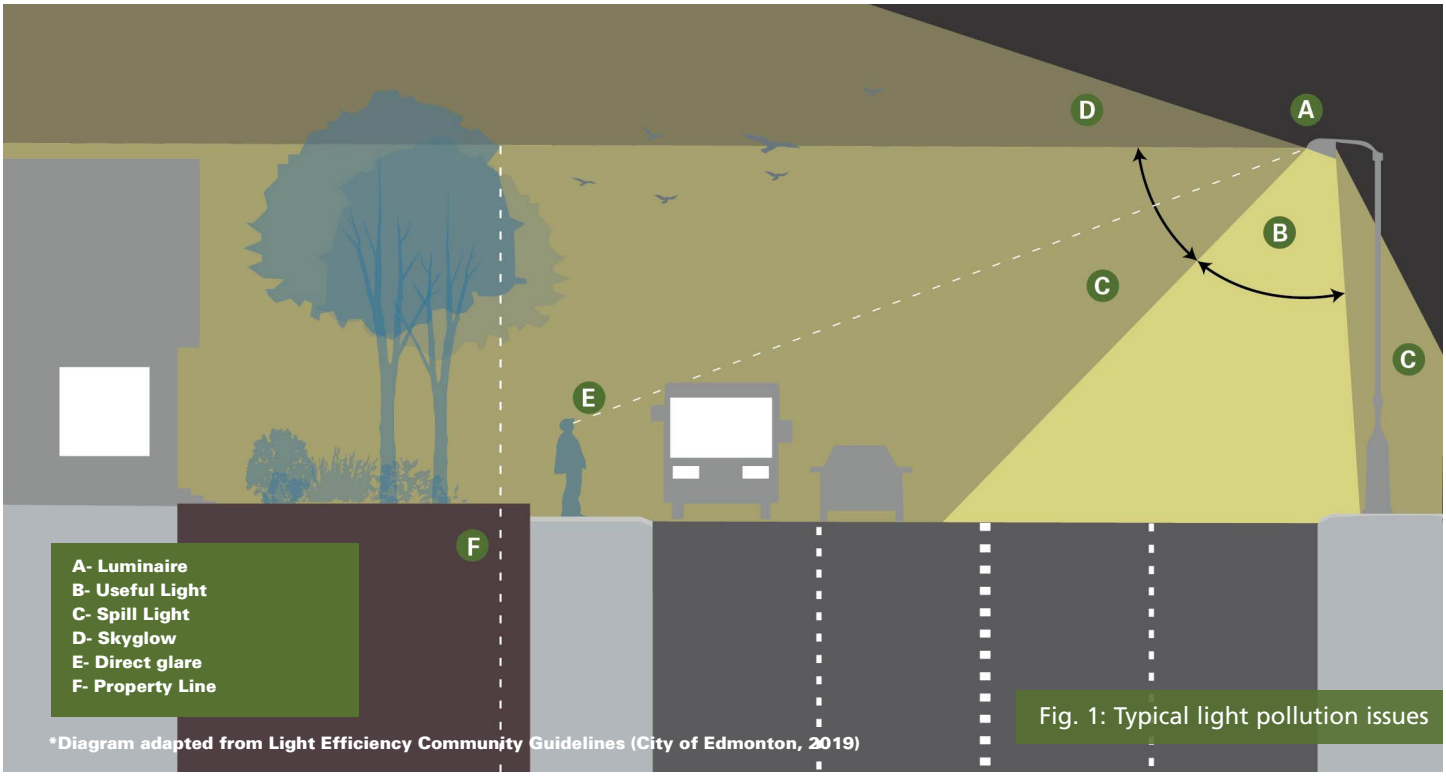


Fig. 1: Typical light pollution issues

Design Guidelines:

- ☑ Use the minimum number and intensity of lights that is appropriate for the use and/or activity.
- ☑ Consider lumens (amount of light produced) rather than watts (amount of energy used) when selecting lighting, and prefer low glare lighting fixtures to reduce excessive brightness and diffuse light. Low glare options can also require less energy.
- ☑ Consider wavelength selection for lighting on a case by case basis, dependent on an assessment of target species.
- ☑ Use longer wave (higher than 560nm) light sources. Amber with minimal blue is best. "Amber" is defined as light in the wavelength of 500 – 700nm.
- ☑ Avoid light with blue/violet (400 – 500nm) and ultra-violet wavelengths (< 400nm). Also, avoid use of white LEDs that contain high short wave blue light components. Most wildlife species are sensitive to shortwave blue/violet light. This light also scatters more readily and contributes to skyglow. [9]

Guilds and Focal Species: All.

Where to Implement: Urban, forested, riparian, marine, and estuarine areas.

What to Watch For:

- ☑ Standard lighting designs may not consider needs of wildlife and may require modification to suit biodiversity objectives.
- ☑ Short wavelength light (e.g., blue) scatters more readily in the atmosphere and contributes to skyglow more so than longer wavelength light.
- ☑ While more energy efficient, some new technology (e.g., LED) can cause more light, increasing light pollution.

2.2.3 ADAPTIVE CONTROLS

Controlled and targeted artificial light management including smart controls and LED technology that allow for instantaneous switching on/off of light and use only when needed, in addition to the remote management of lights.

Design Guidelines:

- ☑ Use smart technology to allow for remote management of lighting, and allow for minimization of lighting output and energy consumption. The latest lighting technology should be used to minimize unnecessary light output and energy consumption.
- ☑ Use lights that are capable of being dimmed when less illumination is needed.

Guilds and Focal Species: All.

Where to Implement: Can be deployed anywhere.

What to Watch For: Requires retrofitting of existing lighting systems and monitoring of smart technology once installed.

<u>Co-benefits of bird-friendly lighting:</u>

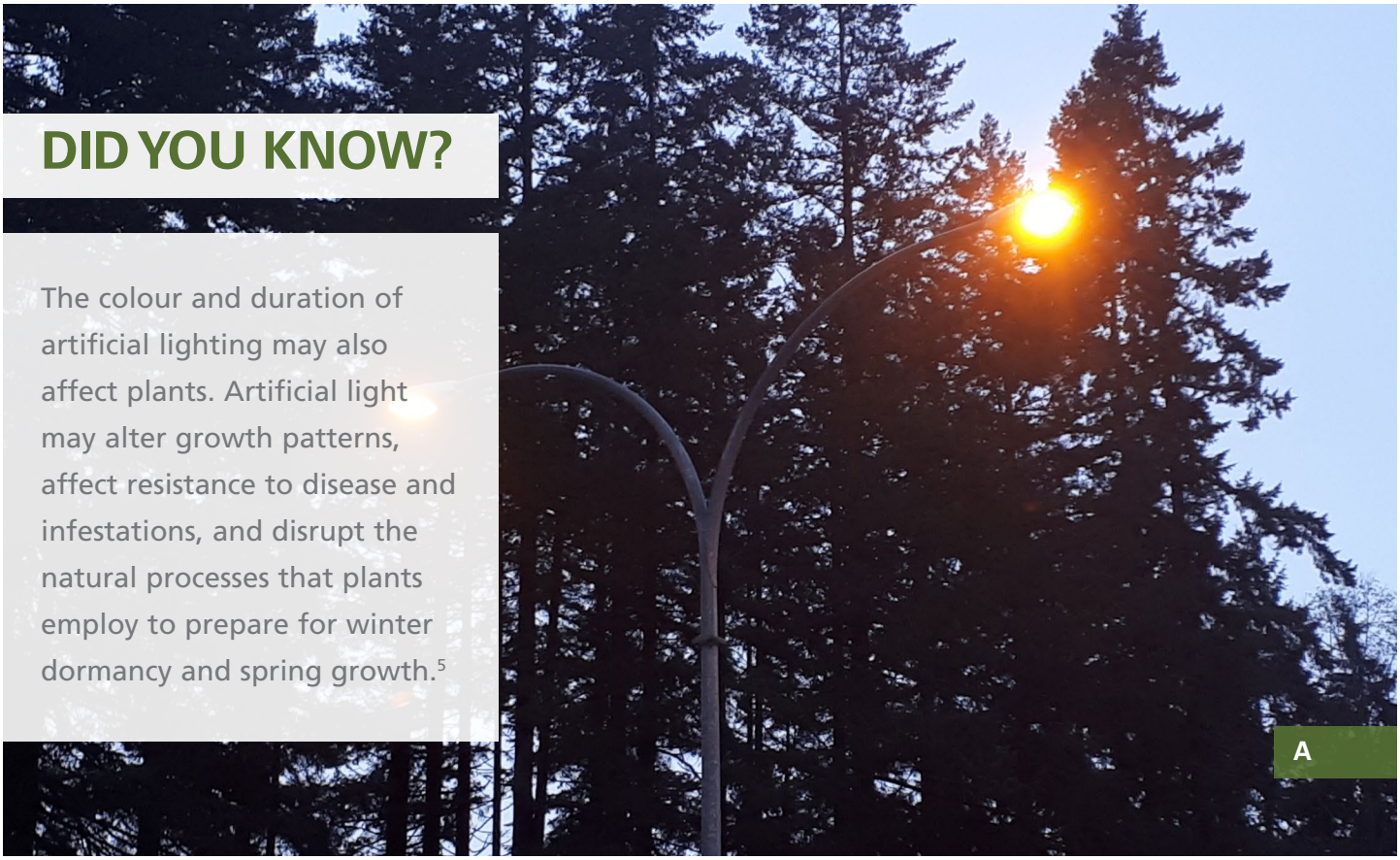
- ☑ Provide cost savings by maximizing areas that can be maintained with natural darkness.
- ☑ Reduce eye fatigue and improve night vision with low glare lights.
- ☑ Reduce energy costs with low wattage and low glare lights.

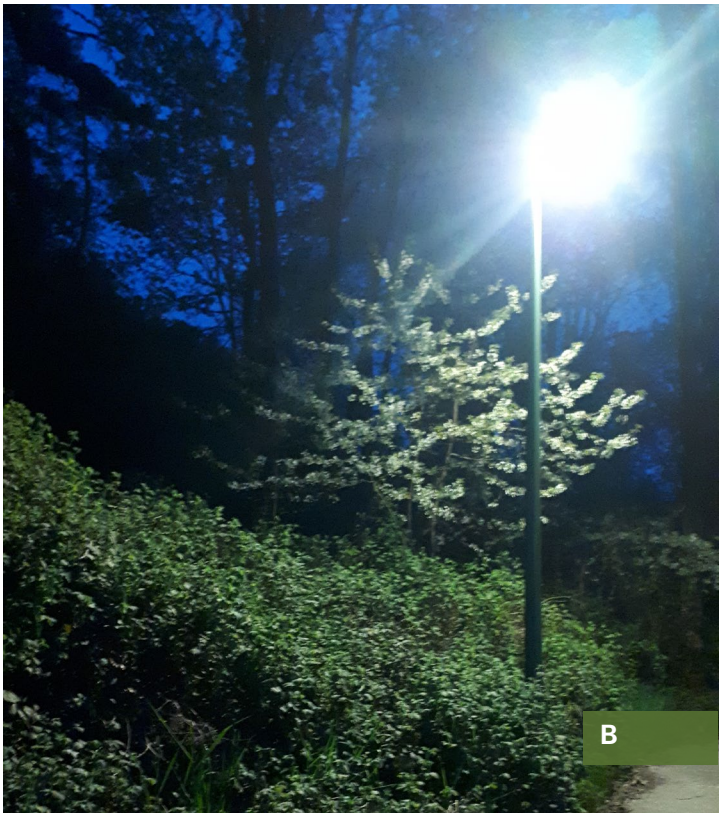
FURTHER READING:

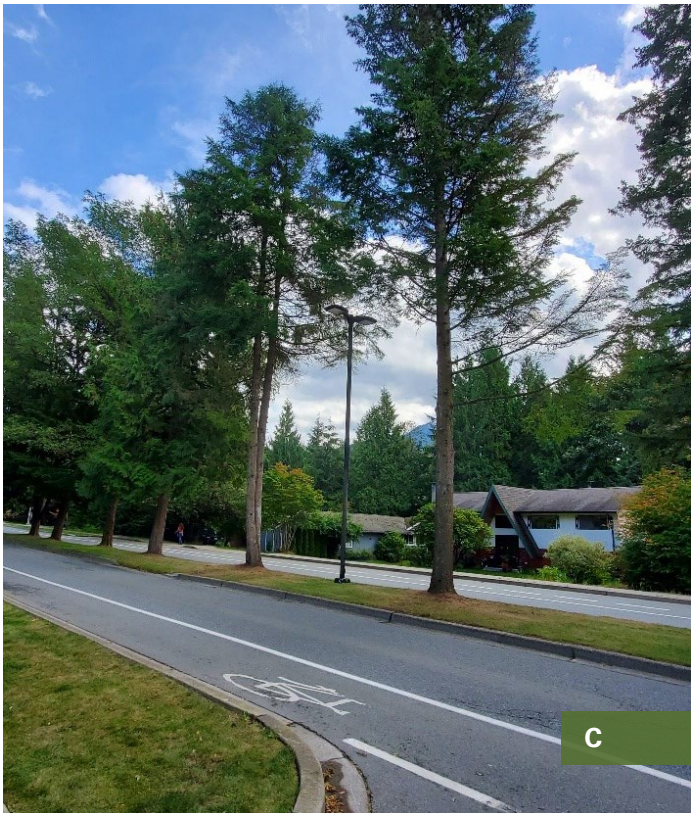
Canadian Guidelines for Outdoor Lighting (Low-Impact Lighting) for RASC Dark-Sky Protection Programs.[4]
National Light Pollution Guidelines for Wildlife Including Marine Turtles, Seabirds and Migratory Shorebirds.[7]

DID YOU KNOW?

The colour and duration of artificial lighting may also affect plants. Artificial light may alter growth patterns, affect resistance to disease and infestations, and disrupt the natural processes that plants employ to prepare for winter dormancy and spring growth.[5]







A - Amber Light Mundy Park Coquitlam - Credit: Pamela Zevit
B - Example of an unshielded white light - Credit: Pamela Zevit
C - Example of a shielded streetlight - Credit: Andrea Buckman

2.2.3 DIRECTIONAL & SHIELDED LIGHTING

Directional lighting is focused at an intended target area and is designed to limit the amount of light that spills outside of the target area boundaries. Shields hide a light source from direct view and can help reduce light reflection. Both directional and shielded lighting can reduce light spill on the ground and light spills that contribute to artificial skyglow.

Design Guidelines:

- ☑ Use directional and shielded lighting to eliminate unintended light spill outside of target areas (where it serves no purpose).
- ☑ Prefer dark-sky compliant full-shielded (i.e., full cut-off) light fixtures that direct light downwards below the horizontal plane and result in no up-light.
- ☑ Ensure fixture is shielded so that lens or lamp is not visible.
- ☑ Modify existing lighting systems by installing shielding to reduce unintended light spill outside of the target area.

Guilds and Focal Species: All.

Where to Implement: Urban, forested, and riparian areas.

What to Watch For: Consider reflective properties of the receiving environment (e.g., light-coloured surfaces).

2.3.3 LOW MOUNTED LIGHTING

Low mounted lighting involves lowering the height of lighting as close to the ground as possible or embedding the light in the ground. This type of lighting can be effective at reducing skyglow, especially when combined with shielding.

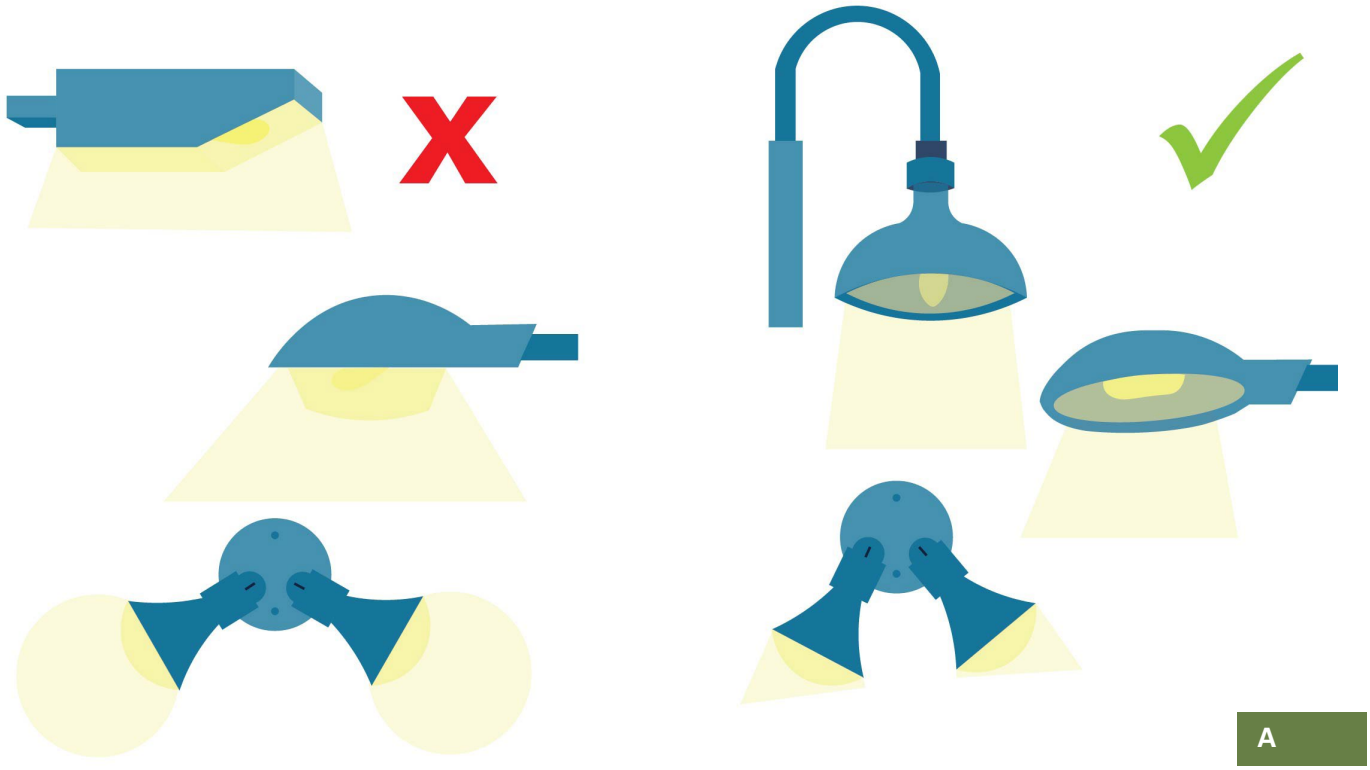
Design Guidelines:

- ☑ Use low-mounted and shielded lighting where appropriate.
- ☑ Mount fixtures as low to the ground as possible (to ensure light reaches ground where it is needed) and reduce visibility of the light source.

Guilds and Focal Species: All.

Where to Implement: Urban Matrix.

What to Watch For: Low-mounted lights on roadways can potentially attract some species of wildlife (e.g., bats) and result in collisions between wildlife and vehicles. Use of non-white LEDs can mitigate this problem. A pilot project in the UK is using "bat-friendly" red LEDs along a stretch of roadway to avoid attracting insects (and the bats that prey on them). Similar programs using bat-friendly lighting in the Netherlands have proven successful along roads and housing complexes. These lights allow bats to behave normally, without affecting their flying or feeding behavior. An example of where this could be employed is along some of Surrey's major GIN Hubs such as Green Timbers Urban Forest, Redwood, and Sunnyside Urban Forest parks.



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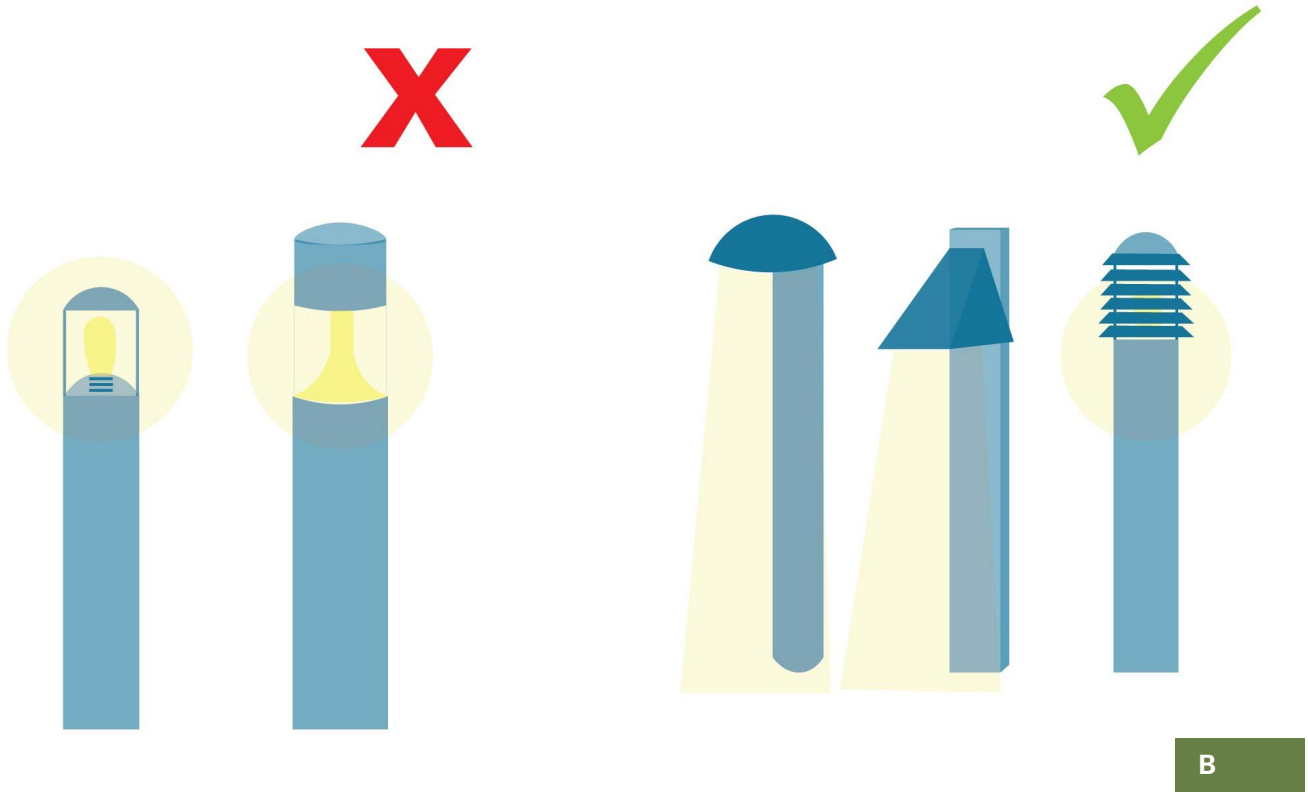


B

A - Fig. 2: Acceptable and unacceptable directional and shielded lighting
B - Fig. 3: Acceptable and unacceptable low mounted lighting
*Diagrams adapted from Light Efficiency Community Guidelines (City of Edmonton, 2019)

NOISE ABATEMENT 02

Context

Noise is defined as 'unwanted' sound. Human-caused noise pollution in urban and rural areas has been demonstrated to have negative effects on biodiversity. In urban environments, human-caused noises are generally louder, more constant, and are stronger at lower frequencies than natural sounds. Noise pollution caused by traffic, industry, and other activities can disturb wildlife by masking animal sounds and inhibiting their ability to communicate, whether that be to detect predators or prey, make distress or alarm calls, or engage in courtship behaviour. Noise pollution can also affect wildlife physiology and behavior, which may be reflected in a species' use of habitat, abundance, reproduction, and survivorship. All animal groups, including mammals, fish, herptiles, and invertebrates can be affected by noise pollution. Noise effects to wildlife have been recorded at levels equivalent to normal human conversation (50dBA).[19, 20]

Types of strategies to manage noise pollution include physical design strategies, regulatory measures, and land use planning. When considering biodiversity, these types of strategies often focus on managing development and activity along interface zones (i.e., developed areas next to the green infrastructure network). However, these strategies can also be adapted elsewhere in the urban matrix where noise effects on different species and habitats may require management.

Key Considerations:

- ☑ Health Canada guidance suggests that background noise levels should not exceed 55dBA outdoors in the daytime and 40dBA at night to protect speech comprehension, restful sleep, and mental health in areas with human receptors (i.e., people and places where people live,work, and play).[21] Slightly higher thresholds are used for intermittent, temporary noise (e.g., blasts). Mitigation employed around human receptors can reduce noise impacts to biodiversity;[22] however, many of those best practices are not observed in more natural areas without human receptors.
- ☑ Even where humans are not present as permanent residents, there is a need to mitigate noise. Various biodiversity (i.e., non-human) receptors can also be negatively affected when background noises increase. Many animal species use vocalizations to communicate, attract a mate, detect predators and prey, and defend territories; these behaviours can be disrupted when noises are increased above species-specific thresholds (e.g., birds, 37 to 48dB [23]; frogs 39-70dB[24].
- ☑ Implementation of more than one type of noise abatement strategy is likely to yield better results.
- ☑ Some physical design strategies (e.g., shields and barriers) have the potential to increase habitat fragmentation and reduce wildlife mobility.
- ☑ A precautionary approach should be used when establishing noise buffers. Locating roads, developments, and other activity away from green infrastructure networks may be preferable to implementing physical design strategies, particularly where information on existing biodiversity is limited.
- ☑ Urban noise, particularly from traffic, can travel many kilometers depending on traffic volume, speed, and weather. The frequency of sound can influence the effectiveness of mitigation measures (e.g., barriers) and potential effects to wildlife.
- ☑ Complementary measures (e.g., traffic calming) may be implemented to further reduce noise in some situations.
- ☑ Ongoing monitoring will be required to assess effectiveness of specific design strategies.

2.4 SOUND BARRIERS

2.4.1 VEGETATIVE BUFFERS

Vegetative buffers are wide and dense corridors with trees of different heights and larger shrubs that can absorb, reflect, diffuse, and scatter sound waves, particularly those in the higher frequencies. Plants can also reduce acoustical ground effects by "softening" soil, which can attenuate noise. Vegetative buffers can include natural areas, shelterbelts, and hedgerows. Optimally, noise reductions attributed to well-planned vegetation buffers in urban environments is in the range of 5 to 10dB over a distance of 30m.[25] Vegetation can also be integrated at small scales (e.g., multiple rows of street trees, vegetative caps on natural barriers) to help attenuate noise, but the reduction in noise levels will not be as significant.

Design Guidelines:

- ☑ Wider and taller tree buffers have greater noise reduction effects.[26, 27]
- ☑ Prefer coniferous trees or a combination of conifers and large-leaved deciduous species. Evergreen species will offer year-round noise control. Deciduous trees with larger leaf areas can attenuate sound more effectively, but are not as beneficial during seasonal leaf drop.
- ☑ Plant tall, dense shrubs to fill in gaps in lower foliage layers of trees. This combination of shrubs and trees is a key factor to reduce noise effects.
- ☑ Select trees with wide trunks. Prefer those species that will keep lower branches intact as they grow to maturity.
- ☑ Plant dense screens with minimal gaps close to the sound source. Consider stems, branches, and leaves when planting for density.
- ☑ Plant trees along roadways as close together as practical and with minor deviations in pattern.
- ☑ Select plants tolerant for conditions (e.g., native species, and air/road contaminants).
- ☑ Integrate topography for noise barriers wherever possible.

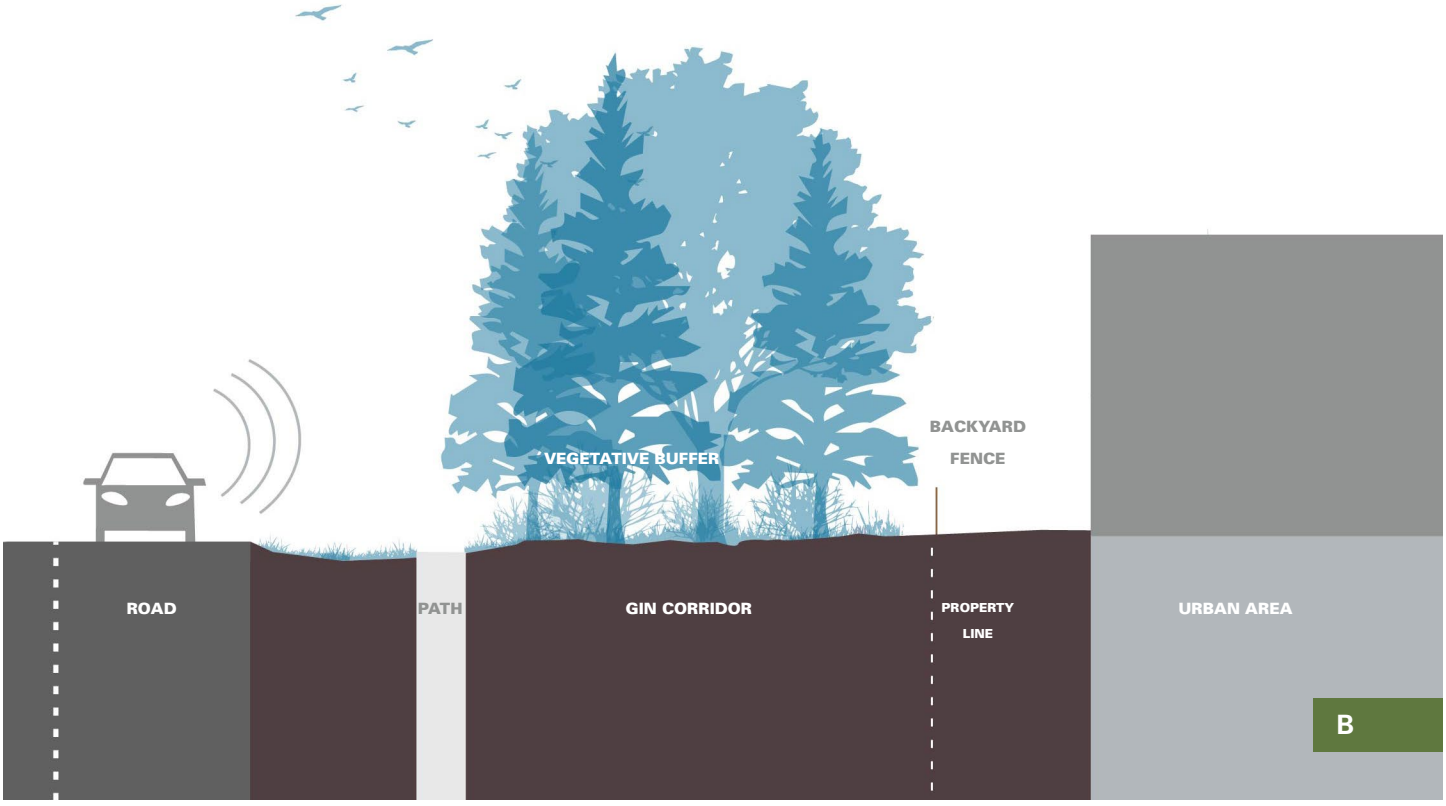
Focal Guilds and Species: All.

Where to implement: Urban, forested, and riparian areas.

What to Watch For: A very wide buffer is needed to attenuate noise effectively. Plant wide buffers where possible (a minimum of 15m but optimally wider than 50m).[28]

Co-benefits:

- ☑ Provide windbreaks.
- ☑ Manage stormwater through canopy interception and increase protection from floods.
- ☑ Capture, absorb, and filter rainwater and overland flow.



A - Existing sound barrier wall, Surrey - Credit: Google Earth
B - Fig. 4: Vegetative Buffer

2.4.2 EARTH BERMS

Earth berms are structures constructed from soil designed to block sound. Earth berms attenuate noise similar to artificial walls and can be visibly appealing and blend into the natural landscape (particularly if they are planted with low vegetation). Earthen structures are durable, have a long lifespan, and low maintenance costs. They can also facilitate wildlife mobility due to their lower slope angle.

Design Guidelines:

- ☑ Wind blowing from source to receiver can reduce the efficiency of noise barriers. Earth berms with gradual slopes less than 18 degrees can negate this effect. Steeper sloped berms with a flat top are also effective.[28]
- ☑ Include large, irregular features and surfaces (e.g., stepped, undulating topography) to attenuate more noise.
- ☑ Adjust berm height based on topography and the type of traffic using the road. Higher berms are more effective at noise reduction; however, higher berms require a wider base which can be a cost and space constraint. Conventional berm height is 3-4m.
- ☑ Consider using artificial barriers in conjunction with earth berms where space is constrained.
- ☑ Plant berms with grasses, forbs, shrubs, and trees (where acceptable) to provide cover and attenuate some noise.[29]

Focal Guilds and Species: All.

Where to Implement: Urban matrix (where space permits), forested, and riparian areas.

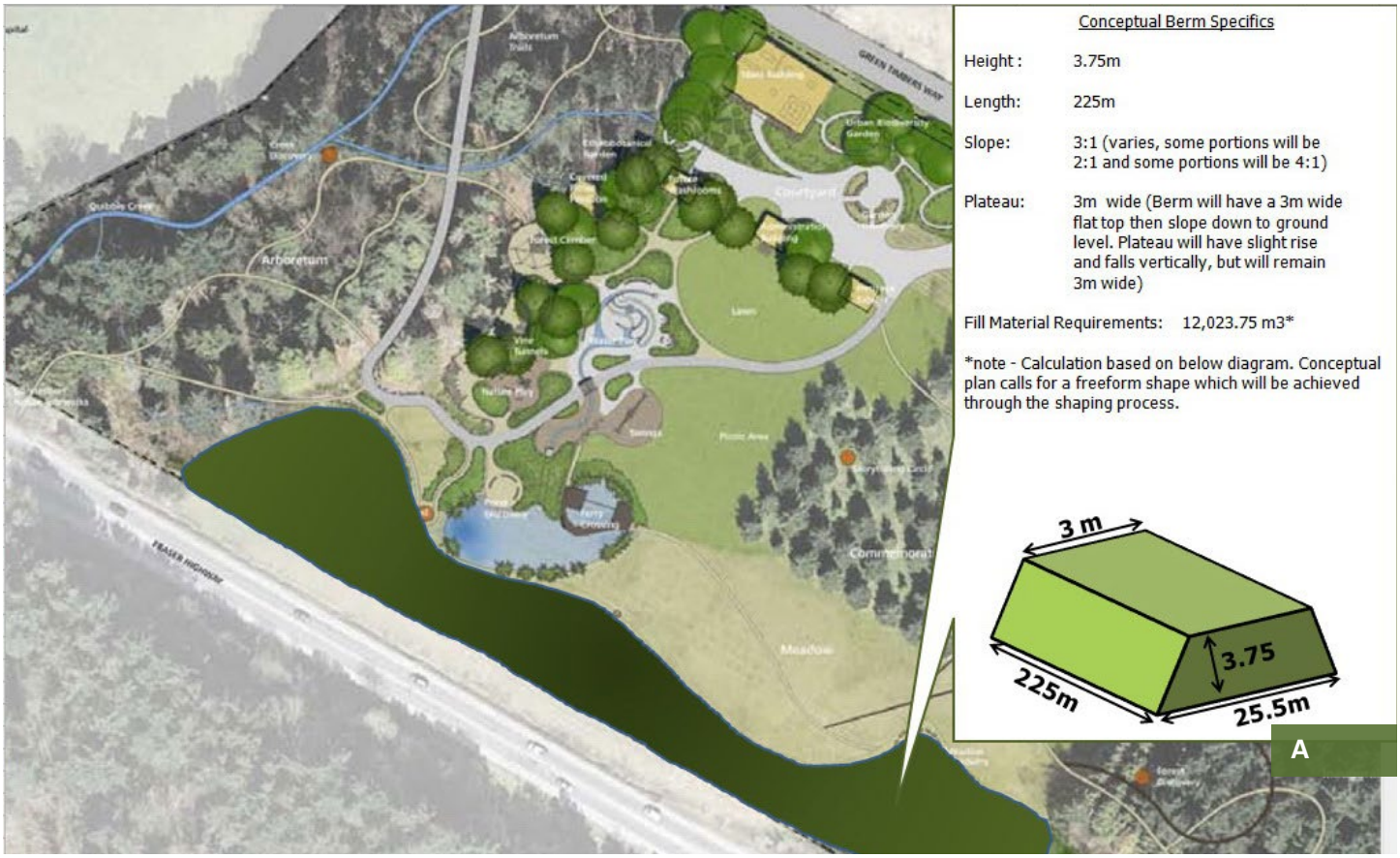
What to Watch For: Ensure that berms do not create a barrier to wildlife passage. Berms may require mowing if vegetation is planted on top of earth berms. Do not plant trees on dykes/berms where structural integrity may be compromised.

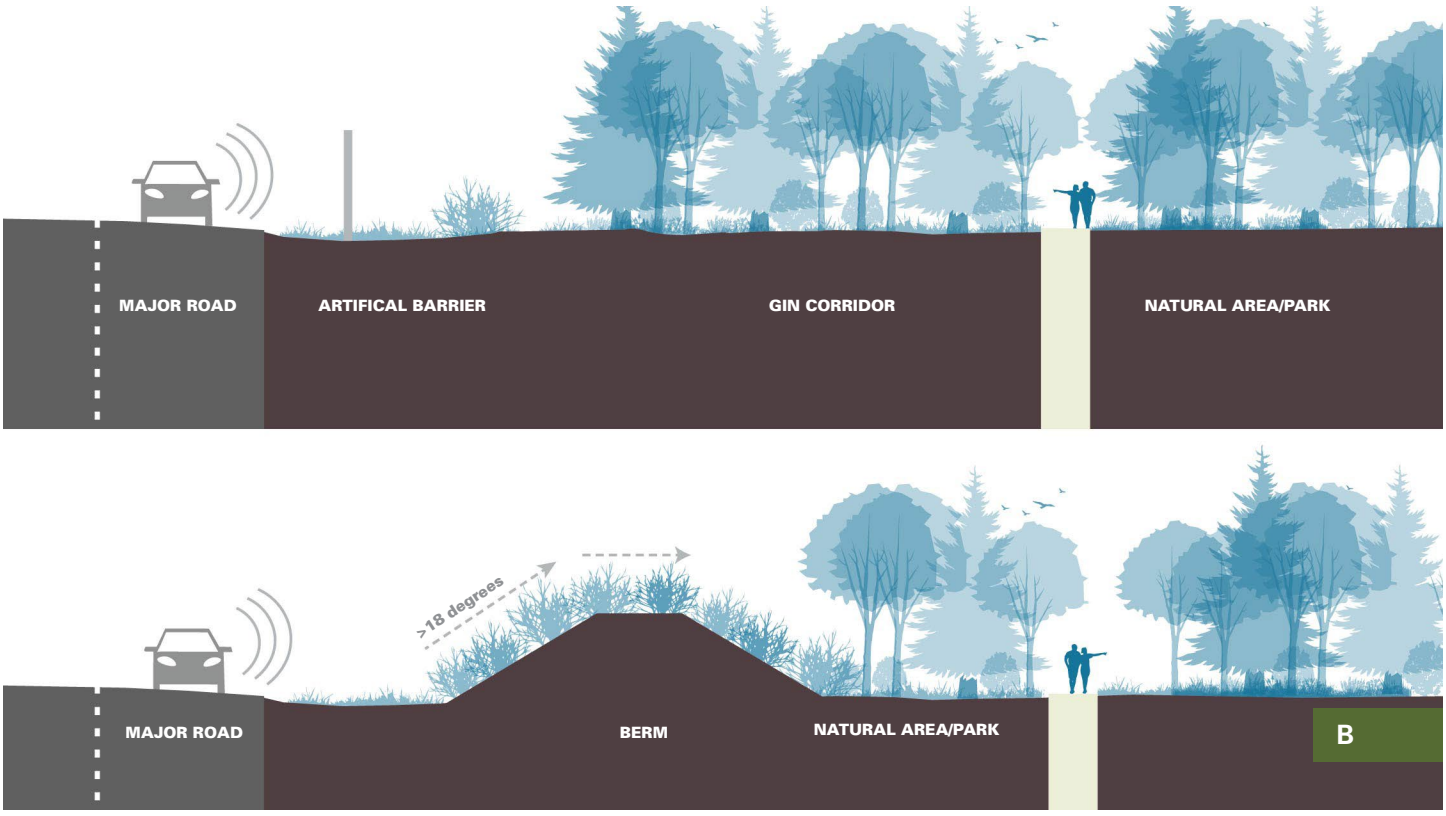
Co-benefits:

- ☑ Recycle construction materials including soil/rock as part of earth berms.
- ☑ Provide natural aesthetic and may be used for trails.

FURTHER READING:

Novel Solutions for Quieter and Greener Cities.[28]





A - Earth berm at Surrey Nature Centre - Credit: City of Surrey
B - Fig. 5: Artificial Barrier vs. Earth Berm.

* Diagram adapted from [Noise Controls Earth Berms: Guidelines for the use of Earth Berms to Control Highway Noise]

2.4.3 LOW-HEIGHT BARRIERS

Low-height barriers generally have a height and width less than one meter. Low barriers can be implemented within the urban matrix next to roads where space constraints do not allow for more significant barriers. Noise reductions of up to 9dBA have been measured when low barriers are constructed next to roadways.[28]

Design Guidelines:

- ☑ Cap barriers with low-density soil, coarser rock, and other natural materials.
- ☑ Prefer lower-gradient slopes to straight barriers to permit wildlife mobility.
- ☑ Roughen slopes and include irregular features (to depth of 25cm).
- ☑ Plant with grass, forb, and shrub species to attenuate noise and provide wildlife cover and forage.

Focal Guilds and Species: All.

Where to Implement: Urban matrix.

What to Watch For: Low height barriers are more effective in urban areas with lower traffic speeds.

2.4.4 ARTIFICIAL BARRIERS

Constructed walls (built of concrete, brick, stone, wood, plastic, laminated glass, and recycled materials like rubber tires or PVC waste) designed to block, absorb, or reflect sound. These barriers can reduce noise between 10 and 20dB depending on design and placement, can be constructed close to sound source, and may be used in conjunction with earth berms or vegetative structures (e.g., green walls).28 Studies have shown green walls to perform better at absorbing noise, particularly low frequency sounds, than similarly constructed non-vegetated barriers.[30]

Design Guidelines:

- ☑ Prefer materials that are high density, relatively low open porosity, and have a high damping ratio.
- ☑ Incorporate vegetation and plant systems into design where possible.
- ☑ Incorporate vegetated substrate (e.g., soil cells) into hard structures.
- ☑ Use low density, porous, granulated soil that can retain moisture to better attenuate noise in the low and medium frequencies.
- ☑ Use stratified, rather than homogenous, materials.

Focal Guilds and Species: N/A

Where to Implement: Urban matrix.

What to Watch For: Artificial barriers may inhibit wildlife movement, reduce visibility, segregate wildlife communities, cause tunnel effects, block sunlight, and create wind turbulence. Incorporate vegetation and plant systems into design where possible.

A - Vegetated retaining wall - Credit: Furbishco
B - Live staking (See Module 1: Habitat Structures)
C - Vegetated retaining wall - Credit: Furbishco

CASE STUDY

Surrey Nature Centre and Parking Lot

Surrey, BC

The Surrey Nature Center (SNC) and parking lot integrate a variety of design strategies that support biodiversity and achieve other co-benefits, including noise and light mitigation and stormwater management.

The SNC is an older development that includes a berm constructed from leftover `fill` taken from an adjacent construction site. The berm was installed between the Nature Centre south meadow and Fraser Highway to mitigate road noise. It is 225m long, 3.75m tall, and has a plateau of 3 m. A trail runs along the top of the berm. Drainage pipe was installed to facilitate natural water flow that would otherwise be impeded. The berm is grassed on one side; alder has naturally regenerated on the side facing the Fraser Highway (see page 20 for schematic diagram).

The parking lot is a new addition that includes ecologically sensitive lighting that aligns with the International Dark Sky Initiative. Low Impact Development methods (e.g., dry pond, infiltration gallery, permeable paving, water treatment/filtration, etc.) have also been applied. A raised boardwalk mounted on ground screws allows root growth and water movement underneath.

Permeable Pavement
Credit: City of Surrey

Boardwalk Installation
Credit: City of Surrey

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