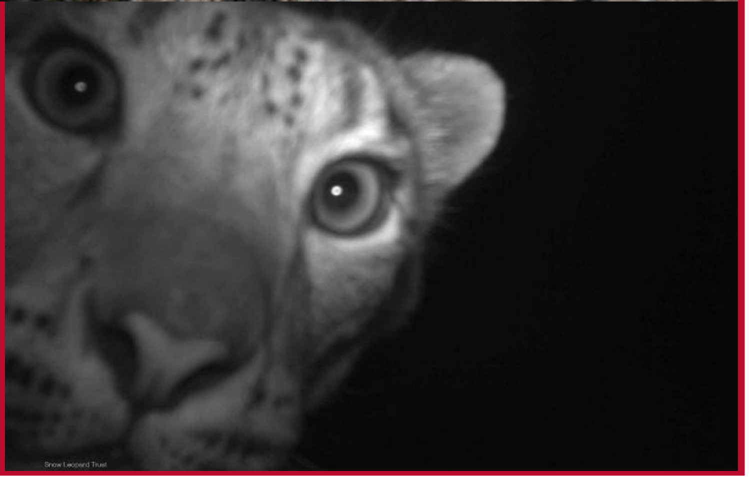
USAID
FROM THE AMERICAN PEOPLE

# BUILDING A FOUNDATION FOR LINEAR INFRASTRUCTURE SAFEGUARDS IN ASIA

## "THE LISA PROJECT"

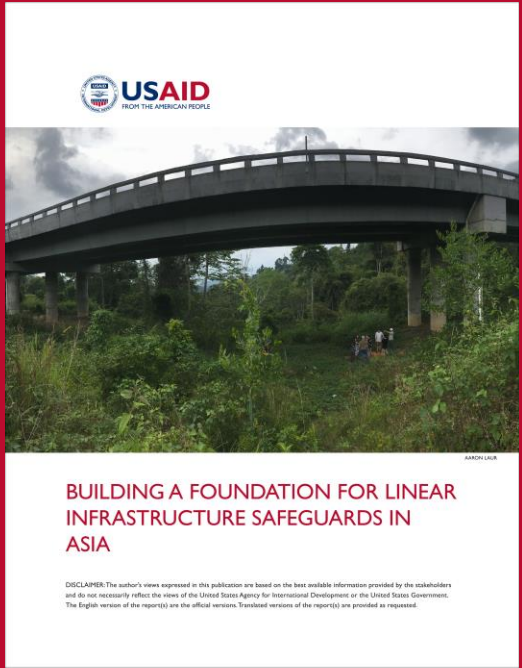
## MODULE 6: ENGINEERING CONSIDERATIONS IN THE DESIGN OF WILDLIFE CROSSINGS AND THEIR INFRASTRUCTURE

Prime Contractor: Perez, APC
ESS Work Assignment #13

# RESULTS OF THE LISA PROJECT

## THE FINAL REPORT


USAID
FROM THE AMERICAN PEOPLE

AARON LAUR

BUILDING A FOUNDATION FOR LINEAR INFRASTRUCTURE SAFEGUARDS IN ASIA

DISCLAIMER: The author's views expressed in this publication are based on the best available information provided by the stakeholders and do not necessarily reflect the views of the United States Agency for International Development or the United States Government. The English version of the report(s) are the official versions. Translated versions of the report(s) are provided as requested.

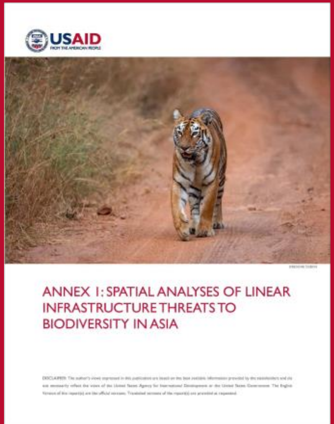
**https://largelandscapes.org/lisa-reports**

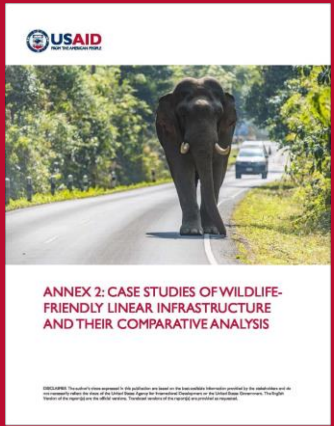
USAID
FROM THE AMERICAN PEOPLE

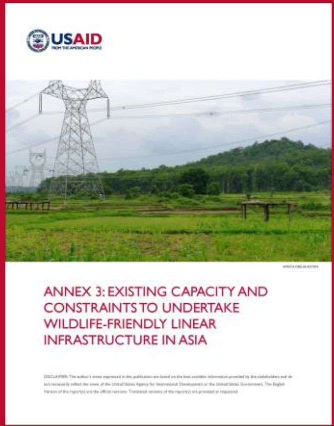
# RESULTS OF THE LISA PROJECT

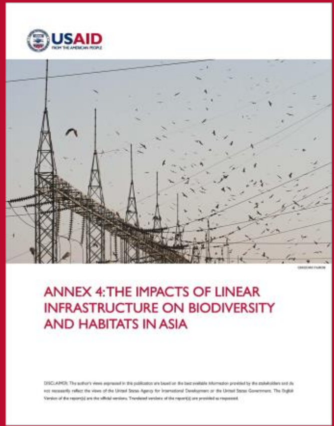
## THE FINAL REPORT'S FOUR ANNEXES

Annex 1: Spatial Analyses
Annex 2: Case Studies
Annex 3: Capacity Assessment
Annex 4: Literature Review



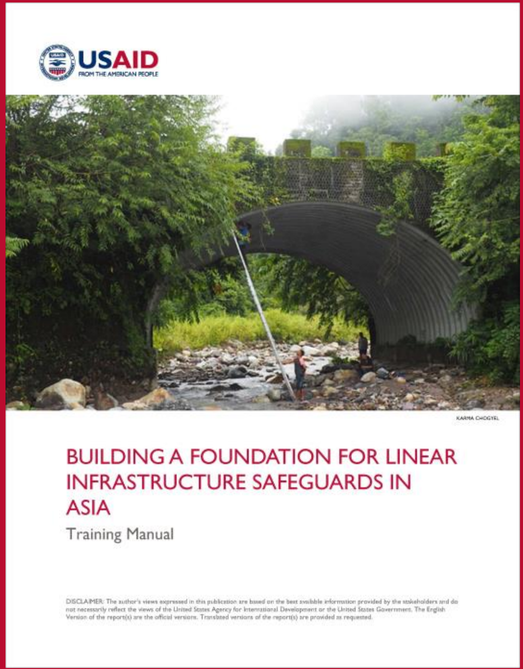




USAID FROM THE AMERICAN PEOPLE

https://largelandscapes.org/lisa-reports/

# RESULTS OF THE LISA PROJECT

## TRAINING MATERIALS AND MANUAL




**https://largelandscapes.org/lisa-training/**

# MODULE 6 PRESENTER:

Terry McGuire, P.Eng.
Transportation Engineer
Parks Canada Agency (retired), Canada

USAID
FROM THE AMERICAN PEOPLE


# ENGINEERING CONSIDERATIONS DESIGN OF WILDLIFE CROSSINGS AND THEIR INFRASTRUCTURE

TERRY MCGUIRE P.ENG

MCGUIRE ENGINEERING

WILDLIFE OVERPASS YOHO NATIONAL PARK CANADA

# PRESENTATION CONTENTS


Part 1 - Introduction

Part 2 - Mitigating Wildlife/Vehicle Collisions

Part 3 - Wildlife Crossing Design

# PART 1: INTRODUCTION

USAID
FROM THE AMERICAN PEOPLE

# PRESENTATION

- Following presentation is primarily from a large mammal, North American perspective based on the Banff National Park, Canada experience and monitoring.

- Asian context could be slightly different.

- While the presentation primarily references and depicts highway crossings, design considerations presented can be equally applied to other linear infrastructure such as railways or canals.

USAID
FROM THE AMERICAN PEOPLE

# WHY MITIGATE WILDLIFE/VEHICLE COLLISIONS

- Provide for wildlife population sustainability
  - Reduce wildlife mortality – especially endangered species
  - Ensure connectivity and biodiversity

- Motorist/public safety
  - Reduce motorist death, injury and property damage costs

USAID
FROM THE AMERICAN PEOPLE

# WILDLIFE/VEHICLE MORTALITY AND CONNECTIVITY SOLUTION

- Involves a two-part mitigation strategy

+

USAID
FROM THE AMERICAN PEOPLE

MUST INCLUDE BOTH !

# PART 2: MITIGATING WILDLIFE/VEHICLE COLLISIONS

USAID
FROM THE AMERICAN PEOPLE

# PASSIVE VS. REACTIVE APPROACH

- Passive = Fencing

- Reactive = Animal Detection by Driver

USAID
FROM THE AMERICAN PEOPLE

# WILDLIFE FENCING DESIGN

USAID
FROM THE AMERICAN PEOPLE

# FENCE DESIGN

- Following presentation is primarily from a large mammal North American perspective based on the Banff National Park, Canada experience and monitoring.
- Asian context could be slightly different.
- Context sensitive design is important when considering fence design and will need to reflect the locale and other factors such as rural vs semi urban.
- Fencing for reptiles and amphibians can be slightly different but many of the design considerations are similar.

# FENCE DESIGN CONSIDERATION

1) Animal Characteristics
2) Degree of Exclusion
3) Fence Alignment
4) Continuous or Intermittent
5) Fence Composition/Longevity
6) Fence End/Opening Treatments

Situational context will also need to be considered in fence design.


USAID
FROM THE AMERICAN PEOPLE

# 1) ANIMAL CHARACTERISTICS

- Size

- Climbers, jumpers, diggers

USAID
FROM THE AMERICAN PEOPLE

# 2) DEGREE OF EXCLUSION

- All or select species
- Seasonality of species
- Continuous or partial fencing
- Number of highway entrances/exits through fence
- Number of fence terminations
- Practicality vs cost


Photo: Terry McGuire

USAID FROM THE AMERICAN PEOPLE

# 2) DEGREE OF EXCLUSION

- Fence fabric/mesh size
  - Woven/page wire, chain link, barbed wire
  - Variable or consistent mesh opening
  - Variable at bottom to deter smaller animals from passing through larger mesh
- Fence Height
  - Addresses jumping over



USAID
FROM THE AMERICAN PEOPLE

# 2) DEGREE OF EXCLUSION


- Buried Apron
  - Addresses access beneath bottom of fence and ground and digging
- Outriggers @ $45^0$ or $90^0$
  - Addresses climbing over


USAID
FROM THE AMERICAN PEOPLE

# 2) DEGREE OF EXCLUSION


- Barbed Wire
  - Addresses climbing over
- Electrification
  - Addresses climbing


USAID
FROM THE AMERICAN PEOPLE

# 2) DEGREE OF EXCLUSION

- Rock rubble
  - Addresses primarily hooved animals
  - Not effective seasonally in high snow areas
- Vertical retaining walls and steep rock cuts/terrain
  - Addresses climbing



USAID
FROM THE AMERICAN PEOPLE

# 3) FENCE ALIGNMENT

Choose alignment carefully considering:

- amount of land being alienated
- constructability and maintenance
- need to have minimum 5 to 7 m cleared ROW
- clear zone and vehicle collisions
- tree blow down,
- aesthetics


USAID
FROM THE AMERICAN PEOPLE

# 4) CONTINUOUS VS. INTERMITTENT


- Design for incursions into right-of-way
  - One way or swing gates


USAID
FROM THE AMERICAN PEOPLE

# 4) CONTINUOUS VS INTERMITTENT

- Need a means to extract wildlife inside fence ROW – jump outs or gates

- Multiple end treatments = higher degree/probability of intrusion into ROW

- Need to allow for vehicles and pedestrian passage through fence

    - fence around where possible


USAID
FROM THE AMERICAN PEOPLE

# 4) CONTINUOUS VS INTERMITTENT

- Design for incursions into right of way
  - Escape ramps (jump outs)
  - Locate close to fence ends and openings
  - Design high enough to preclude jumping or climbing back


Photo: Terry McGuire

USAID
FROM THE AMERICAN PEOPLE

# 5) FENCE DESIGN AND LONGEVITY

- Post spacing 4.2 to 5.4 m
- Environmentally friendly preservative treated wood posts
  - 20 to 30 years for softwood
  - 12 cm line and 16 cm dia corner posts
  - 3.7 to 4.2 m long ( 2.4 m high fence)
- Galvanized steel
  - 3.7 m long
  - 8 cm dia posts



USAID
FROM THE AMERICAN PEOPLE

# 5) FENCE DESIGN AND LONGEVITY

- Steel "tee" fence posts

# 5) FENCE DESIGN AND LONGEVITY

- Concrete
  – Cast-In-Place
  – Precast/ Panels

- Other possibilities
  – Recycled plastic
  – Fiberglass
  – Fiber Reinforced Epoxy



USAID
FROM THE AMERICAN PEOPLE

# 5) FENCE DESIGN AND LONGEVITY

- Fabric
  - Class III zinc galvanized mesh (tensile strength 1390n/mm$^2$)
  - 15 to 20 yrs before rust showing ( 8 to 10 if Class I)
- Mesh
  - 15 -18 cm square opening if constant mesh
  - 8 cm high gradually increasing from bottom up if variable mesh

# 5) FENCE DESIGN AND LONGEVITY

- Adjustable bracing at vertical or horizontal directional changes
- Need to consider expansion/contraction (115kg @ 20C)
  - Design bracing to be adjusted to maintain tension over time
- Consider high tensile top cable in treed areas to address tree blow down



USAID
FROM THE AMERICAN PEOPLE

# 6) FENCE END/OPENING TREATMENTS

- Rock rubble or natural terrain as a barrier
- Clear or create game trails to direct animals away from opening
- Tie-in to natural and manmade terrain such as rock cuts, waterbodies or retaining walls



USAID
FROM THE AMERICAN PEOPLE

# 6) FENCE END/OPENING TREATMENTS

Cattle (Texas) Gate


Electrified Cattle Gate


Electromat

# 6) FENCE END/OPENING TREATMENTS

Railway spike mat


USAID
FROM THE AMERICAN PEOPLE

# 6) FENCE END/OPENING TREATMENTS

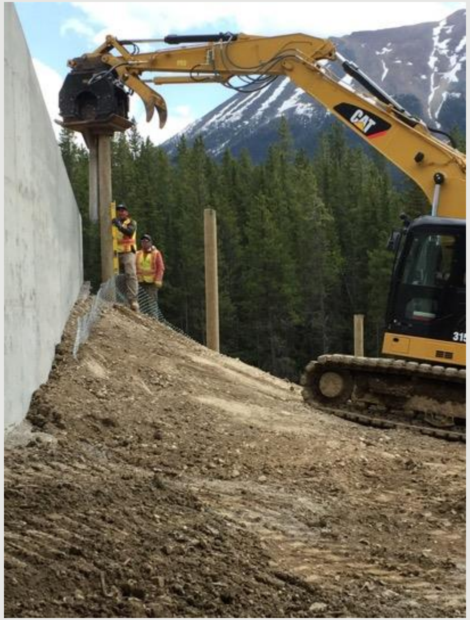
- Year-round pedestrian access consideration needed

Photo: Terry McGuire

USAID
FROM THE AMERICAN PEOPLE

# FENCING INSTALLATION

- Advance fence mesh installation equally on both sides of right-of-way
- Install mesh on the highway side of post




# FENCING INSTALLATION

- Ensure fence alignment provides access to culvert ends


- Install buried apron first prior to installing posts and fabric


USAID
FROM THE AMERICAN PEOPLE

# FENCING COSTS

Asia costs may be significantly different. Table intended to provide an order of magnitude comparison

| Wildlife Fence (Posts on 5 m spacing) | Cost/km (2019 $ USD) | 10 % Design/Supervision/km (2019 $ USD) | Total Cost/km (2019 $ USD) |
|---|---|---|---|
| Wood posts c/w apron | $ 80,000 | $ 8000 | $ 88,000 |
| Wood posts no apron | $ 62,000 | $ 6200 | $ 68,200 |
| Steel posts c/w apron | $ 88,000 | $ 8800 | $ 96,800 |
| Steel posts no apron | $ 71,000 | $7100 | $ 78,100 |

**Jump outs = $5,300 USD**
**Animal Guard = $40,000 USD**

USAID
FROM THE AMERICAN PEOPLE

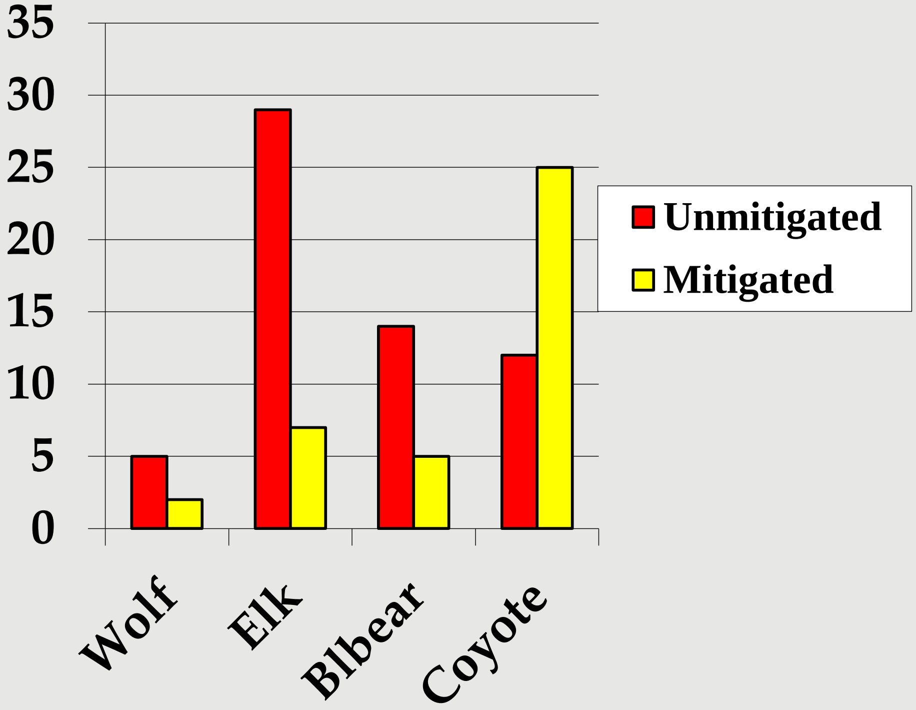
# ADAPTIVE MANAGEMENT

- Expect the unexpected
  - Ability to squeeze through tight places
  - Fence blocks natural escape routes
- Field Testing
  - Pilot fence design and monitor if uncertain before large scale installation


USAID
FROM THE AMERICAN PEOPLE

# FENCING EFFECTIVENESS

- Based on Banff National Park Canada measurements
  - Fencing effective in reducing wildlife/vehicle collisions despite increased traffic volumes
  - 80% overall reduction
  - 95% for elk, deer and moose




Source T Clevenger unpublished

# ROADSIDE ANIMAL DETECTION TECHNOLOGY

- Warning triggered by animal presence.
  - Lidar
  - Thermal
  - Radar
  - Buried Cable
  - Animal Deterring Devices
  - In Car

USAID
FROM THE AMERICAN PEOPLE

# ROADSIDE ANIMAL DETECTION TECHNOLOGY

- Variable success
  - Terrain
  - Weather conditions
  - Evolving Technology
  - Most importantly DRIVER ATTITUDE !

Photo: Terry McGuire

USAID
FROM THE AMERICAN PEOPLE

# SUMMARY THOUGHTS

USAID
FROM THE AMERICAN PEOPLE

# KEY LESSONS LEARNED AND ADVICE

- It is important to establish a multi-disciplinary team to design and field locate wildlife fencing.
- Establish quantitative fencing goal(s)(i.e., collision reduction overall or by species) to guide design and subsequently monitor to measure success.
- Consider/anticipate changing habitat as result of climate change (fire).
- Fence ends and breaks are most problematic from controlling unwanted access to highway and railway right-of-way.
- Overall effectiveness of animal guards and electric mats is variable.
- Animal guards noisy and not recommended across roads 30 kph and or moderate traffic volumes

# KEY LESSONS LEARNED AND ADVICE

- Fencing can be a long term maintenance issue especially in forested areas and depends on fence composition/construction/alignment.
- Avoid 'out of sight out of mind' fencing alignment.
- Correct installation by contractors is important.
- Avoid bottom of slope installation to prevent jump over.
- Anticipate and adapt to wildlife issues.
- Fencing should encompass both roads and railways where they run parallel and close proximity to each other.
- Fencing is a formidable barrier to wildlife movement and must not be installed without provision of crossing structures.

# QUIZ QUESTION 1

What is the most important consideration in fence design?

a) degree of exclusion being sought

b) target species

c) maintainability

d) choice of fence material

USAID
FROM THE AMERICAN PEOPLE

# QUIZ QUESTION 1 ANSWER

What is the most important consideration in fence design?

**a) degree of exclusion being sought**

*While all four choices are design considerations, the most important factor is the degree of exclusion being sought as this influences the choice of fence composition, cost, and maintainability while reflecting the species to be prevented from accessing the highway or railway right-of-way.*

USAID
FROM THE AMERICAN PEOPLE

# QUIZ QUESTION 2

Fencing alone is an appropriate linear infrastructure wildlife vehicle collision mitigation strategy.

a) True

b) False

USAID
FROM THE AMERICAN PEOPLE

# QUIZ QUESTION 2 ANSWER

Fencing alone is an appropriate linear infrastructure wildlife vehicle collision mitigation strategy.

**b) False**

*While fencing is effective in preventing WVCs and resulting wildlife mortality, it prohibits wildlife from moving from one side to the other of the road or railway to access needed habitat, food, and water, and to ensure over the long term gene flow and genetic connectivity.*

USAID
FROM THE AMERICAN PEOPLE

# PART 3: WILDLIFE CROSSING DESIGN

# CROSSING DESIGN

- Following presentation is primarily from a large mammal perspective.

- Crossings for fish, reptiles and amphibians can be slightly different but many of the design considerations are similar.

# GENERAL DESIGN CONSIDERATIONS

- Variety of structure types/sizes
- Underpass vs overpass
- Topography conducive for type of crossing envisaged
- Geotechnical - Soil and water table conditions at proposed site
- Meteorological
- Utilities
- Seismic
- Building codes and acts
- Restrictions (easements, property lines, archeological)


USAID
FROM THE AMERICAN PEOPLE

# GENERAL DESIGN CONSIDERATIONS

- Maintain existing vegetation cover close to crossing
- Take advantage of existing terrain (depressions, ridges)
- Take advantage/enhance existing game trails
- Last but not least - budget


USAID
FROM THE AMERICAN PEOPLE

# CROSSING STRUCTURE COST BREAKDOWN

| | % TOTAL COST |
|---|---|
| • Substructure (piers, footings, piling, abutments) | 20 |
| • Superstructure girders, deck, railings) | 50 |
| • Approaches | 5 |
| • Context sensitive( aesthetics, landscaping) | 5 |
| • Design, tender, sureties, bonding | 5 |
| • Construction supervision | 10 |
| • Miscellaneous (traffic control, mob/demob, environmental) | 5 |

USAID
FROM THE AMERICAN PEOPLE

# UNDERPASSES (UNDERCROSSINGS)

Wildlife pass beneath road or railway

Photo: Bilal Habib, Wildlife Institute of India

# UNDERPASS DESIGN CONSIDERATIONS

- Provide clear view through structure(s) (avoid doglegs or staggered structures)
- Avoid steep approach/exit grades
- Consider climate change - flooding
- Be cognizant of noise and light
  - Avoid expansion joints (integral or semi integral abutments)
  - Deck surface
  - Barrier height


USAID
FROM THE AMERICAN PEOPLE

# UNDERPASS OPENESS RATIO CONSIDERATION

- Rule of thumb convention has been (hxw)/l = 1 or more
- I believe usage more influenced by species characteristics
    - Ungulates larger openness vs cats accepting of smaller openness
- Other considerations being
    - Geometry of opening
    - Interior lighting/noise
    - Motivation of animals to cross


USAID
FROM THE AMERICAN PEOPLE

# UNDERPASS STRUCTURE ALTERNATIVES

- Buried arch/culvert style
- Combined with existing bridge/culvert
- Flyover

NOTE : Tunnels and long elevated sections of road are a category onto themselves and not discussed here

USAID
FROM THE AMERICAN PEOPLE

# BRIDGE STYLE UNDERPASSES


Multiple span bridge > 20 m


Simple Single Span < 20m

# ADVANTAGES AND DISADVANTAGES

- Advantages
  - Common engineering design
  - Familiar to government departments, contractors

- Disadvantages
  - Need to deal with expansion/contraction from joints- noise
  - Long term maintenance
  - Vibration
  - Cost ($4500/m$^2$ USD)

USAID
FROM THE AMERICAN PEOPLE

# BURIED BRIDGE/CULVERT STYLE UNDERPASSES


Corrugated structural steel multi-plate


Large precast concrete culvert

USAID
FROM THE AMERICAN PEOPLE

# BURIED BRIDGE/CULVERT STYLE UNDERPASSES


Steel multi-plate or simple culverts


Concrete box culvert

And even small drainage culverts are a crossing opportunity not to be ignored

USAID FROM THE AMERICAN PEOPLE

# ADVANTAGES AND DISADVANTAGES

- Advantages
  - No expansion/contraction – noise eliminated
  - Short construction timelines
  - Minimal maintenance
  - Cost less than conventional bridge
  - Minimal expensive engineering – supplier provided design
  - Familiar to government departments, contractors
- Disadvantages
  - Width/height limitations for buried bridges/culverts
  - Traffic disruption during installation

# EXISTING BRIDGES/CULVERT UNDERPASSES DUAL PURPOSE



Benching provisions

USAID
FROM THE AMERICAN PEOPLE

# EXISTING BRIDGES/CULVERT UNDERPASSES DUAL PURPOSE


Photo: Terry McGuire

# ADVANTAGES AND DISADVANTAGES

- Advantages
  - Minimal cost
  - Traffic disruption during installation

- Disadvantages
  - Can affect stream crossing hydrology/flow if after thought

# FLYOVER UNDERPASSES


USAID
FROM THE AMERICAN PEOPLE

# ADVANTAGES AND DISADVANTAGES

- Advantages
  - Wildlife remains free to travel at grade

- Disadvantages
  - Costly
  - Need the right terrain
  - Potential traffic disruption during installation

USAID
FROM THE AMERICAN PEOPLE

# KEY CONSIDERATIONS

Crossing width selection is a critical decision

Recognize contextual setting

Clear understanding of goals/objectives and how success will be measured

Be opportunistic to possibilities such as combining with bridge rehabilitation /expansion



USAID
FROM THE AMERICAN PEOPLE

# OVERPASSES (OVERCROSSINGS)

Wildlife pass over the road or railway


USAID
FROM THE AMERICAN PEOPLE

# OVERPASS DESIGN CONSIDERATIONS

Single span vs multiple spans



USAID FROM THE AMERICAN PEOPLE

# OVERPASS DESIGN CONSIDERATIONS

Buried vs ‘traditional’ bridge

33% lest cost experienced for buried



USAID
FROM THE AMERICAN PEOPLE

# OVERPASS DESIGN CONSIDERATIONS

- Width across structure critical design decision – base on species and contextual setting as opposed to simply replicating what others have done

- Traffic clearance envelope


USAID
FROM THE AMERICAN PEOPLE

# OVERPASS DESIGN CONSIDERATIONS

- Minimal live load needs to be considered
- Design deadload from soil biggest factor (potential asymmetric loading caused by earth berms)
- Waterproof crossing structure surface to prevent leakage through structure
- Site remoteness



USAID
FROM THE AMERICAN PEOPLE

# OVERPASS DESIGN CONSIDERATIONS

- Crossing structure is for animals not traffic
- Permit some differential settlement

# OVERPASS DESIGN CONSIDERATIONS

- Flare out approach to help guide/funnel wildlife to crossing
- Parabolic shape ideal for structure although flare out approach to help guide/funnel wildlife to crossing also works
- Approach slope is an important consideration
  - Max 3:1 – flatter being better
  - Ideally tying into a ridge
- Maintain existing vegetation as close to start of slope as possible


Photo: Terry McGuire

USAID FROM THE AMERICAN PEOPLE

# OVERPASS DESIGN CONSIDERATIONS

- Diversify the landscape across structure – open spaces along with longitudinal strips of vegetative cover help accommodate movement and provide habitat

- Install rocks, deadfall, root wads to create habitat and cover for small mammals and reptiles

- Consider ponds and water features


Photo: Terry McGuire

USAID
FROM THE AMERICAN PEOPLE

# OVERPASS DESIGN CONSIDERATIONS

- Landscaping of structure plays an important role in its success
  - Choose soil depth that will retain moisture but reflective of vegetation to be planted (less for grass vs trees)
  - Plant seedlings vs mature vegetation
  - Use native plants harvested from nearby locations vs nursery stock
  - Avoid edible forage
  - Rely to some measure on volunteer growth
- Design surface contouring to self irrigate to specific areas and plant there


USAID
FROM THE AMERICAN PEOPLE

# OVERPASS DESIGN CONSIDERATIONS

- Sound and light attenuation an important
  - Use earth berms, fences, gabion walls and vegetation to create screening
- Recognize that what may appear inexpensive such as berms takes up costly real estate and affects structural design
- Need to consider/understand contextual setting
  - Sound & lighting level approaching/ in vicinity of structure should match that on the structure



USAID
FROM THE AMERICAN PEOPLE

# OVERPASS STRUCTURE ALTERNATIVES

- Bridge style
- Buried bridge(arch) style

USAID
FROM THE AMERICAN PEOPLE

# BRIDGE STYLE OVERPASS

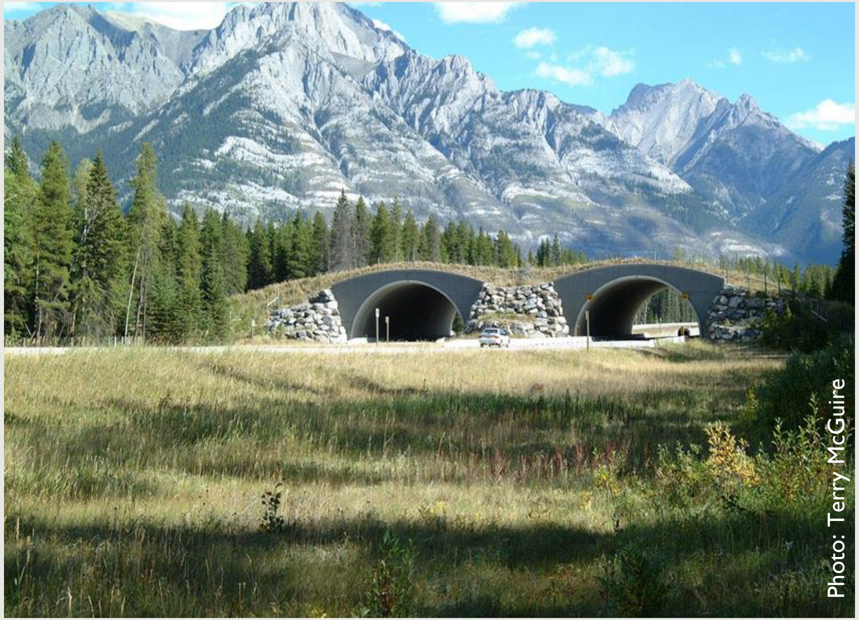
Photo: Terry McGuire

# ADVANTAGES AND DISADVANTAGES

- Advantages
  - Common engineering design
  - Familiar to gov't departments, engineers, contractors
  - Minimal disruption to traffic

- Disadvantages
  - Dealing with expansion/contraction but no noise
  - Potential Vibration
  - Maintenance (expansion joints under fill)
  - Cost ($4,500 USD/m$^2$)

# BURIED BRIDGE (ARCH) STYLE OVERPASS


USAID
FROM THE AMERICAN PEOPLE

# ARCH OVERPASS DESIGN CONSIDERATIONS

- Minimum traffic disruption
- Low maintenance
- Best suited where grade high on both sides of highway
- Carry significant deadload efficiently due to soil structure interaction
- Easily accommodates soil for native planting
- Arched top sheds water eliminating pooling
- Cost effective spread footing design



USAID FROM THE AMERICAN PEOPLE

# OVERPASS DESIGN CONSIDERATIONS – ARCH GEOMETRICS

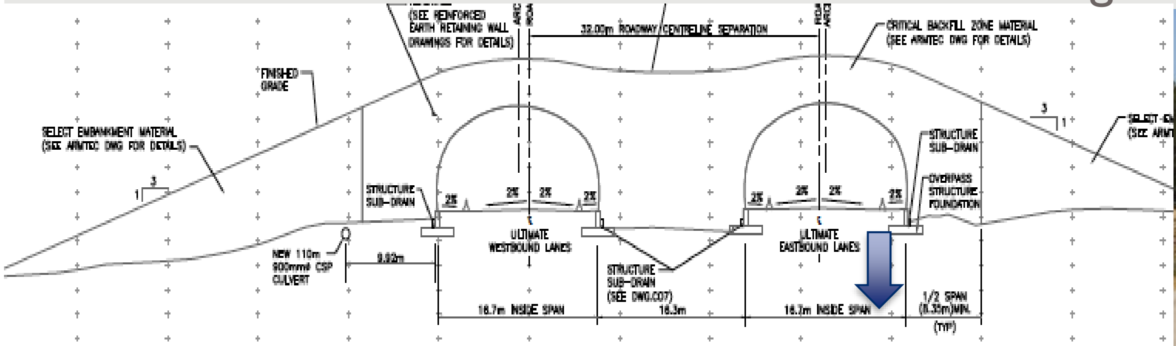
- Semi circular shape influences height and costs
- Flatter elliptical shape reduces height and backfill quantities, hence costs while still spanning width
- Flatter arches create greater structural design challenges



USAID
FROM THE AMERICAN PEOPLE

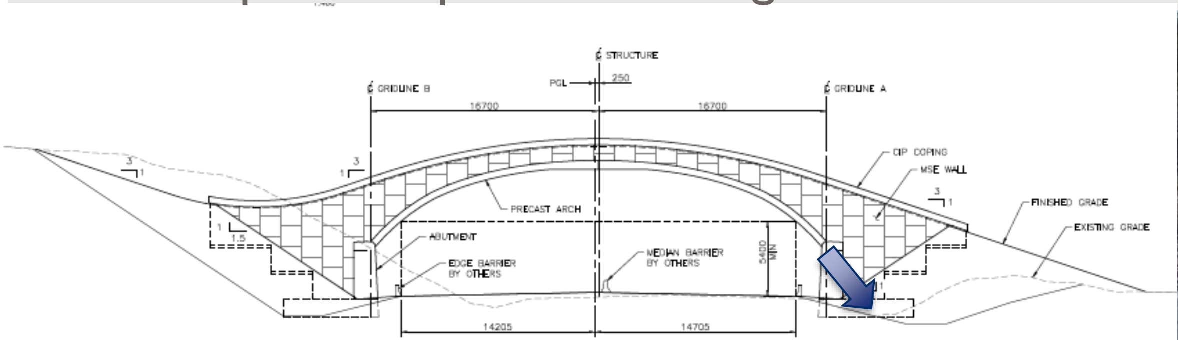
# OVERPASS DESIGN CONSIDERATIONS – ARCH GEOMETRICS

## Semi circular arch – creates vertical load at footing





## Flatter elliptical shape reduces height but creates lateral loading




# OVERPASS DESIGN CONSIDERATIONS - END TREATMENTS

- Beveled vs vertical mechanically stabilized earth (MCS) walls
- Potential savings with beveled end walls



USAID
FROM THE AMERICAN PEOPLE

# OVERPASS DESIGN CONSIDERATIONS - END TREATMENTS

- Utilize existing soil – good option for disposal of excess and unsuitable soils
- Manufacture select backfill on-site

Photo: Terry McGuire

USAID
FROM THE AMERICAN PEOPLE

# OVERPASS DESIGN CONSIDERATIONS - END TREATMENTS

- Utilize alternate materials to reduce weight
- Create habitat for sound/light attenuation berms



USAID
FROM THE AMERICAN PEOPLE

# ADVANTAGES AND DISADVANTAGES

- Advantages
  - No need to expend design dollars - Take advantage of supplier capability - Multiple proprietary systems available – BeBo Arches, Atlantic Industries
  - Arch overpasses are economical and structurally efficient- Adoption of arch design by others bears out conclusions
  - Minimal disruption to traffic
  - Speed of erection
  - Minimal maintenance
- Disadvantages
  - Transportation agency hesitancy/unfamiliarity
  - Span length under 33 m

# ARCH COMPOSTION ALTERNATIVES

- Concrete – Precast
- Steel
- Wood
- Fiber Reinforced Epoxy (Bridge in a Backpack by AIL)

USAID
FROM THE AMERICAN PEOPLE

# GENERAL ARCH OVERPASS DESIGN CONSIDERATIONS

- Arch can be cast in place but easily built from precast concrete or structural corrugated steel
- Design/build most common using proprietary designs
- Usually only require shallow footings
- Detour easily constructed or can be constructed without


USAID
FROM THE AMERICAN PEOPLE

# PRECAST CONCRETE ARCH OVERPASS

- Precast in a factory controlled environment setting offsite
- Good quality control


# PRECAST CONCRETE ARCH OVERPASS

- Simple strip footing can be constructed along side highway with minimal traffic disruption

- Trucked to site as needed from factory



USAID
FROM THE AMERICAN PEOPLE

# PRECAST CONCRETE ARCH OVERPASS

- Relatively short erection time per arch
- No falsework required
- Possibility exists to erect without detours
- Waterproofing, backfill, headwalls and landscaping add time but again minimal disruption to traffic
- Large quantities of backfill required

# STRUCTURAL CORRUGATED STEEL ARCH OVERPASS

- Design/build – manufacturer proprietary information
- Material easily delivered to site
- Erection does not require large cranes
- No special trades - Local labour
- Short erection time
- Simple strip footing can be constructed along side highway with minimal traffic disruption



USAID
FROM THE AMERICAN PEOPLE

# STRUCTURAL CORRUGATED STEEL ARCH OVERPASS

- May require detouring of traffic during erection
- Greater care required in selecting and placing backfill material
- More difficult to waterproof due to bolt connections and expansion/contraction of metal
- Need to consider galvanizing thickness or splash walls in winter climate



USAID
FROM THE AMERICAN PEOPLE

# FENCING COSTS

Asia costs may be significantly different. Table intended to provide an order of magnitude comparison

| Crossing Type ( over/under 2 lane roadway) | Construction Cost (2019 $ USD) | 15 % Design/Supervision (2019 $ USD) | Total Cost (2019 $ USD) | Cost (2019 $USD) |
|---|---|---|---|---|
| **Buried Arch Style Bridge (60m wide)** | $ 2.4 million | $ 0.36 million | $ 2.76 million | $46,000/m width |
| **Bridge Style Underpass (20m long x 14 m wide,500)** | $ 1.33 million | $ 0.20 million | $ 1.53 million | $ 5,500/$m^2$ |
| **4 x 7 m CSP Elliptical Culvert ( 26 m long)** | $ 0.47 million | $ 0.07 million | $ 0.54 million | $ 20,770/m length |
| **3.6 x 3.4 m Concrete Box Culvert (24 m long)** | $ 0.33 million | $ 0.05 million | $ 0.38 million | $15,835/m length |

USAID
FROM THE AMERICAN PEOPLE

# QUIZ QUESTION 3

One size fits all: Wildlife crossings are all relatively generic and can be duplicated based on designs used elsewhere in the world.

a) True

b) False

# QUIZ QUESTION 3 ANSWER

One size fits all: Wildlife crossings are all relatively generic and can be duplicated based on designs used elsewhere in the world.

**b) False**

*Each wildlife crossing is unique and must be undertaken in a contextually sensitive manner. Crossing structures must be built to reflect not only the requirements from a target species' perspective but also its budget and setting, location, and site nuances.*

# QUIZ QUESTION 4

In the design of wildlife underpasses, which of the following is not likely a consideration?

a) Soil conditions

b) Dead load

c) Height and width of structure

d) Live load

USAID
FROM THE AMERICAN PEOPLE

# QUIZ QUESTION 4 ANSWER

In the design of wildlife underpasses, which of the following is not likely a consideration?

**b) Dead load**

*Wildlife underpasses direct animals to pass beneath road or railway and have little or no vegetation. The dead load they carry is similar to any highway or railway bridge structure with the greatest loading being the live load to be carried. Height and width of structure as well as soil conditions are considerations in any structural underpass design.*

# QUIZ QUESTION 5

Which of the following is considered essential in the implementation of an effective wildlife crossing?

a) Large budget

b) Good location

c) Good data

d) Diverse design team

USAID
FROM THE AMERICAN PEOPLE

# QUIZ QUESTION 5

Which of the following is considered essential in the implementation of an effective wildlife crossing?

**d) Diverse design team**

*While all the factors listed are good to have, they can be overcome to some degree save for the lack of a diverse team of not only design engineers, but also others knowledgeable about the species that the structure is being designed to serve. An ideal group of experts needed to consult with engineers includes biologists, road/railway ecologists, landscape architects, suppliers, and contractors. It is through early collaboration in the design process and the understanding and sharing of various perspectives and considerations that a truly effective crossing can be realized.*

USAID FROM THE AMERICAN PEOPLE

# SUMMARY THOUGHTS

USAID
FROM THE AMERICAN PEOPLE

# KEY LESSONS LEARNED AND ADVICE

- 'It takes a team' - It is important to establish a multi-disciplinary team early in the design process and to participate throughout. Don't work in isolation.
- Establish quantitative goal(s)(i.e., connectivity/genetic by some or all species) to guide design and subsequently monitor to measure success.
- Consider/anticipate changing habitat and resulting wildlife usage as result of climate change (extreme weather events, fire).
- Check and consider future highway or railway expansion or changes to adjacent land usage.
- Use of structures by humans for habitation and hunting/poaching may be on-going issue.

# KEY LESSONS LEARNED AND ADVICE

- Wildlife crossings design no mystery. Essentially follows standard engineering procedures/process for any type of bridge structure.
  - Biggest difference is minimal live load and larger deadloads resulting from soil, moisture retention and vegetation (anticipate increase weight result of growth)
  - Leave vegetation to establish on its own – avoid nurturing/watering
- Bridge style structures similar to any highway bridge - regular inspections of structure, bearings and expansion joints.
- Maintenance is really not an issue especially for buried arches
- Leave vegetation to establish on its own – avoid nurturing/watering

# KEY LESSONS LEARNED AND ADVICE

- Important to undertake design from a context sensitive design perspective to reflect situation, setting, etc.
- Crossing location is not necessarily exact with potential to locate within reasonable proposed location to suit from an engineering perspective.
- Drop a soil test hole at proposed locations early in design process to determine site suitability from an engineering perspective.
- Establishing overpass crossing width not an exact science
  - may require risk tolerance
  - avoid simply replicating or relying on big is better
  - has significant cost implications.
  - consider contextual setting
- Berms on crossing structures for light and sound attenuation can be expensive based on structural space/area they take up.

USAID
FROM THE AMERICAN PEOPLE

# KEY LESSONS LEARNED AND ADVICE

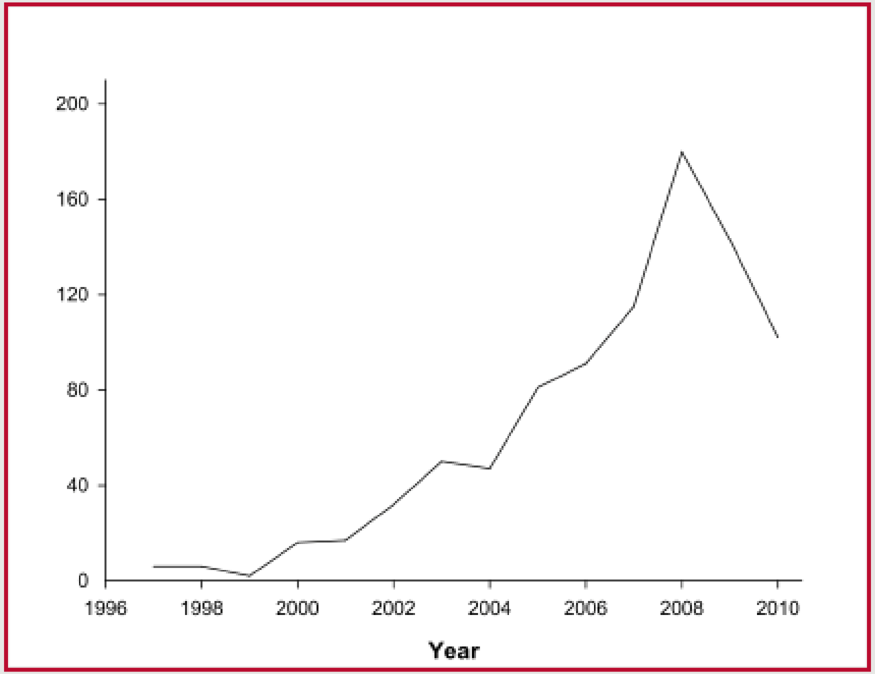
- Ideally offer a ’ buffet/smorgasbord of choices” – Offer frequent and varied crossing opportunities.
- One size or type of structure does not necessarily meet all species requirements.
- Home range/territory of animals may dictate number of crossing opportunities required (especially true regards aerial species, reptiles, etc.)
- Don’t be too singular or target species(s) focused.
- Use crossing opportunities to benefit others including aquatic species, reptiles, insects, bats, etc. by adding appropriate measures such as cover, roosting possibilities.
- Not all crossings need to be large and expensive.

# KEY LESSONS LEARNED AND ADVICE

- Don't ignore drainage culverts (especially ones that flow intermittently) as potential wildlife crossings with some modification (shelves, benching)
- Take advantage of bridge rehabilitation programs to introduce wildlife crossing opportunities by slightly lengthening structure and creating passage opportunities.
- Take advantage of existing stream and river crossings to modify scour rip rap by adding benching and other provisions to facilitate wildlife movement
- Fencing must accompany cross structures.
- Fencing should be of sufficient distance each died of crossing (dependent on species and home range) to guide/funnel wildlife to crossing to prevent end around movement.

# KEY LESSONS LEARNED AND ADVICE

- Be prepared to monitor for an extended period of time




Crossings by grizzly bears

# CLOSING THOUGHTS

- Usage/monitoring data scarce from an Asian setting – Are North American results transferrable?
- Consider using graphics to let people know purpose of structure and build awareness/support
- **Context-sensitive solutions reflective of the situation remain the most critical element in crossing design**

?
=

USAID
FROM THE AMERICAN PEOPLE

# THANK YOU

## CONTACT INFORMATION:


Terry McGuire, P. Eng.
terry.mcguire@shaw.ca
1 403 671 3517


USAID
FROM THE AMERICAN PEOPLE