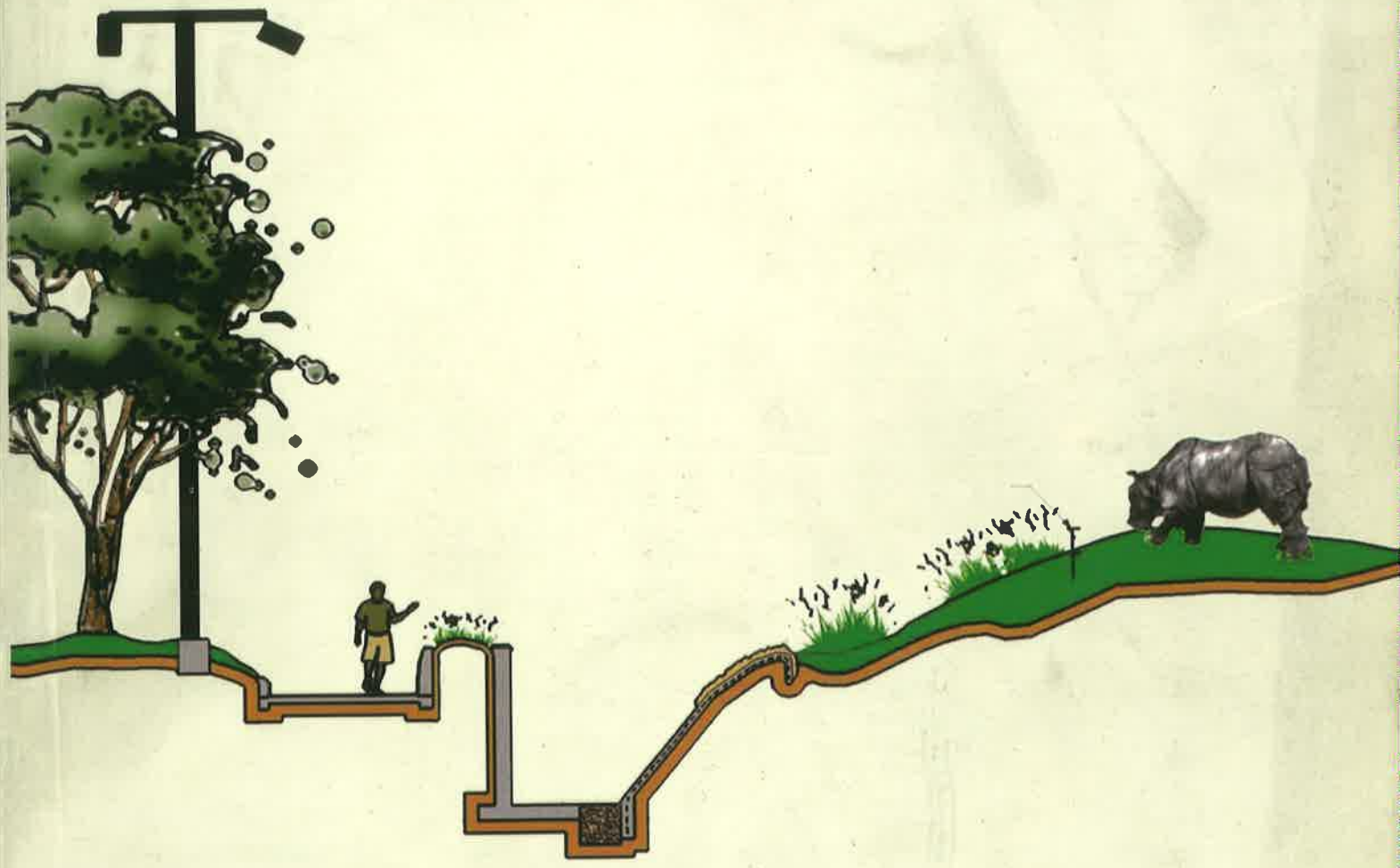
BARRIER DESIGNS for Zoos



Central Zoo Authority
(Ministry of Environment & Forests)

DR. BRIJ KISHOR GUPTA

BARRIER DESIGNS
FOR ZOOS

Central Zoo Authority
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by

Dr. Brij Kishor Gupta

The Central Zoo Authority (CZA) was created by the Government of India through an amendment of the Wild Life (Protection) Act, in 1992. The main objective was to enforce minimum standards and norms for upkeep and healthcare of animals in zoos and to restrain mushrooming of unplanned and ill conceived zoos that were cropping up as adjuncts to public parks, industrial complexes and wayside. The Central Government, in exercise of the powers conferred by Section 38A and sub-section (1) of Section 38B of the Wild Life (Protection) Act, 1972, had constituted the Authority for the first time in February, 1992. The term of the Members of the Authority is fixed for three years. As of now, the Authority has been reconstituted six times. The term of the current Authority expires in September, 2010. The Minister of State for Environment & Forests (Forests& Wildlife) is the ex-officio Chairman of the CZA.

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FOREWORD

This set of guidelines on the barrier design for selected captive animals to help the Zoo Managers to design the animal enclosures keeping in view of the welfare of animals, zoo keepers and at the same time the cost effective naturalistic design among the Indian Zoos is the result of initiative taken by the Central Zoo Authority (Ministry of Environment & Forests) in pursuance of the National Zoo Policy, 1998 and Recognition of Zoo Rules, 1992.

It is aimed that the present document to assist the zoos in achieving improved quality in exhibit design and to ensure that the large naturalistic immersion exhibits for the benefit of zoo animals and the purposes of environmental education. These guidelines have been evolved after analyzing various documents, papers available on the subject and existing exhibit design at various zoos.

The Central Zoo Authority has a Sub-committee on Zoo Designing comprising of experts on the subject who have deliberated in detail on the issues to prepare basic guidelines for barrier design for selected captive animals. The Committee headed by Dr. B. R. Sharma, Member Secretary, Central Zoo Authority and Shri S. K. Patnaik, Principal Chief Conservator of Forests (WL), Orissa (Retd.) who with other members of the Committee have discussed in detail during various meetings. I must commend Dr. Brij Kishor Gupta, Scientific Officer, Central Zoo Authority who has put all the efforts to compile and prepare the final report. The suggestions made by the members of the Sub-committee of Zoo Designing were incorporated and the final draft was approved by the Technical Committee in its 46th meeting of the Central Zoo Authority held on 01.08.2007.

It is expected that all the State Government and those operating zoological parks in the country would take positive steps for the development of naturalistic display by using the appropriate barrier design which should be friendly for the animal housed therein as well as for the management of the zoos.

31/10/07

(S. REGUPATHY)

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PREFACE

The barrier design in the captive facilities where animals are kept for the display to the public to prevent direct contact between the visiting public and the animals play a very important role. Today, the cage bar type enclosure has been eliminated Physical and visual barrier are replaced by moats, many of which are hidden, to contain the animals and to permit unobstructed views of the exhibit display. The use of vegetation, rock work, logs, glass or plastic/ acrylic fronted enclosures, fencing as a barrier, wet or dry moats, or a combination of these and other material are being used effectively today to prevent escape of the animals, injuries to visitors and animals alike.

The present publication "Barrier Design for selected captive animals" is first of its kind and has been compiled by Dr. Brij Kishor Gupta, Evaluation & Monitoring Officer, Central Zoo Authority. I am confident that this manual will go a long way in helping Zoo Managers to plan & construct animal enclosures in their Zoo by providing unobstructed view by providing hidden barriers, creating long panoramas and simulations of their natural habitats where visitors will discover animals that seem to roam freely as of in their "natural habitats".

(Dr. B. R. Sharma)
Member Secretary
Central Zoo Authority

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I am grateful to many people for making possible this publication on Barrier Design. First I would like to thank Shri S. C. Sharma, Addl. DGF (WL), MOEF (Retd.) and Shri P. R. Sinha, Director, Wildlife Institute of India, Dr. B. R. Sharma, Member Secretary, Central Zoo Authority, Shri S. K. Patnaik, Retd. Addl Principal Chief Conservator of Forests (Wildlife), Orissa, Dr. L. N. Acharjyo and Ms. Sally Walker, who encouraged this writing and publication of this manual. Dr. Jon Coe, Landscape Architect for editing the earlier draft of the guidelines, Mr. Adit Pal and Mr. Bernard Harrison for providing detailed illustrations without whom it would have not been possible to bring out this publication. I would also like to acknowledge with thanks the intellectual guidance provided by the Shri T. Ramakrishna, Retd. Principal Chief Conservator of Forests. Andhra Pradesh. I would also like to thank the following for their contribution to the data and comments: Shri A. V. Joseph, Additional Principal Chief Conservator of Forests (Wildlife), Andhra Pradesh; Shri K. N. Banerjee, Ex. Curator, Nehru Zoological Park, Hyderabad; Dr. N. Krishna Kumar, Ex. Director, Arignar Anna Zoological Park, Chennai; Dr. E. Narshimulu, Ex. Curator, Sri Venkateswara Zoological Park, Tirupati; Shri Sanjeev Kumar Gupta, Ex Curator, Indira Gandhi Zoological Park, Vishakhapatnam; Shri D.N. Singh Director, National Zoological Park, New Delhi; Shri R. Bhattacharjee, Ex DFO, Assam State Zoo, Guwahati; Shri G. P. Sharma, Ex Director, Prince of Wales Zoological Gardens, Lucknow, Dr. A Dubey, Ex Veterinary Officer, Kanpur Zoo, Kanpur. Last but not the least, this publication could not have been written without the support of my parents, family members particularly my wife. Thanks are also due to Shri Bipul Chakrabarty for guidance and Shri Vivek Goel, Data Processing Assistant, CZA for help in data analysis. Thanks are also due to Madhu Bala Pramod Kumar Jha, Gopal Swamy and Thakur Das for their help in locating the files and xerox works.

Bengal tigers at Indira Gandhi Zoological Park, Vishakhapatnam (Brij Kishor Gupta)

In the wildness is the preservation of the world.

–Henry David Thoreau

1.0 Introduction

At the beginning of the twenty-first century, zoo exhibit design around the world is in developmental phase that includes thematic display of ecological niches, simulation of animal's natural habitats, and the creation of mixed species exhibits. Today the quality of a zoo is no longer measured by the number of species it contains, but rather by the quality of its exhibits, its educational programs, and its research and conservation activities. Over the past 5 years zoo exhibit design in India has undergone a metamorphosis which has resulted in a significant improvement in the quality of animal care at the major zoos. The impetus behind this has been the establishment of the Central Zoo Authority (statutory body under the Ministry of Environment & Forests, Govt. of India) in 1992.

However, recent surveys have shown that in the majority of Indian zoos most animals are still kept in cages. It is time to eliminate all such cage structures and provide physical and visual barriers through moats and other means. Today exhibit cages in many older zoos have been removed, retiring cubicles and off exhibit breeding area for many specialized species have been created. The use of screens, moats, glass, wire and elevated boardwalks etc are a few options used as barriers for the display of animals. In a zoo the authenticity and quality of the exhibits will form the most immediate as well as the most enduring impressions for the visitor.

Today there are several methods employed to hide animal barriers from public viewing such as disguising the barrier as some natural feature like a stream, rock outcrop, eroded bank or a river edge and so on. The use of vegetation, rocks, logs and similar props help in creating long panoramas containing various animals and an illusion of the animals within a "natural habitat". The barrier may also be hidden by plantings or contouring. By making it impossible, or at least difficult, for visitors to determine exactly what are the physical limits of the animal's area, a greater excitement can be generated and deeper sense of being part of the animal's world.

Barrier design involves issues such as critical jumping distances, structural stability of the barrier, as well as public safety. At present the most moated zoo exhibits are in United States and the moat widths used there are still considered the standard for most zoo architects.

An issue that most zoos around the world, and particularly in India, have to deal with in some form or the other is the harassment of animals. This may take place through remote means i.e. throwing of objects, or by direct means where visitors enter the enclosure. Many zoos feel that harassment can be avoided by providing high enough barriers. However, to do so would defeat the very purpose of a zoo for visitors to learn about and feel empathy for animals through respect. Harassment of animals is an aspect that can only be effectively dealt with through effective zoo management and education of

visitors. Some zoo designers believe there to be a greater tendency for visitors to throw things at zoo animals when the visitors are positioned above the animals. When animals are postioned at higher elevations than the visitors, there is much less animal harassment.

Though public safety is the most important factor to be kept in the mind while designing an exhibit barrier, it is much more than a method to keep the public, and animals out of harms way. There are several physical and even psychological issues involved with barrier design. This manual, while being only recommendatory in nature, seeks to provide zoo staff information on barrier dimensions used around the world. It also suggests best practices for barrier design.

Zoos in India

Though there is historical evidence of zoo established by Jahangir in seventeenth century and one by the Raja of Tanjor (Thanjavur) in eighteenth century, the first public zoo was reportedly established

Bear enclosure at Alipore Zoo

Leopard enclosure at Udaipur Zoo

Bear enclosure at Jaipur Zoo

Aviary at Jodhpur Zoo

in Barrakpore in Calcutta (now Kolkata) in 1801 as a part of Natural History Project and continued till 1978, when remaining animals were transferred to Alipore zoo. This was followed by a private zoo called Marble Palace Zoo in Kolkata which is still functioning.

Peoples Park, Madras, (now Chennai) was established in 1855. This park no more exists and a new zoo at Vandalur has come up in 1985 in its place. Major zoos at Mumbai, Thiruvanthapuram and Lucknow come up in the later part of 19th century and prior to independence. Many zoos like Junagarh, Jaipur, Hyderabad (Old), Udaipur, Thanjavur, Vadodara, Mysore, Gwalior and Bikaner and Jodhpur were established by erstwhile rulers during this period. Though effort was made by some of those zoos to provide large and even moated enclosures, most of the animals were confined to cage like heavy steel structures, with minimal or no attention for providing naturalistic environment.

The role of zoos as repository of wildlife and centres for conservation awareness was realized by Government of India soon after independence and an open moated zoo was established in Delhi in 1959. State Governments also followed suit, and several well planned zoos covering extensive areas were set up in many big cities. Such zoos constructed naturalistic enclosures with moats (dry and wet) as barriers for exhibiting animals for example the Ariganar Anna Zoological Park, Vandalur, Chennai and Indira Gandhi Zoological Park, Vishakhapatnam. However, even today zoos with space constraint such as the Kamla Nehru Prani Sangrahalaya, Indore, V.O.C. Park Zoo, Coimbatore, Lucknow Zoo, State Museum & Zoo, Thrissur and many others, cannot provide large moated enclosures and other solutions have to be used.

Open moated enclosure for elephants at Indira Gandhi Zoological Park, Vishakhapatnam

However, to meet the recreation needs of the people a large number of menageries and mini zoos were also established wherein little attention was paid to the well being of the animals and their management on scientific lines. The decades of 1970s and 1980s witnessed manifold increase in the number of such establishments which at the time were thought to be appropriate but now they are need of major changes.

2.0 Barriers: An Overview

2.1 Barrier Design Issues

2.1.1 Barrier Dimensions

In a zoo, barriers are needed at animal exhibits to separate animal from visitors. The barrier will always be a physical barrier and may also combined with a visual barrier. The Central Zoo Authority in the "Recognition of Zoo Rules" has also emphasized the same. In designing a barrier, since the primary concern is public safety, it is important to know the behaviour and biology of the species to be displayed, so that the minimum depth and width of the barrier can be maintained to prevent animal escape.

2.1.2 Moats vs. Cages

The main advantage of having a moated enclosure is to have an open naturalistic enclosure where the animals may display their natural behaviour. Today, caged enclosures at Kamla Nehru Zoo, Ahmedabad, Alipore Zoo, Kolkata, Gandhi Zoo, Gwalior, Thiruvananthapuram Zoo etc. are being replaced by naturalistic moats. By comparison, zoos at Tirupati, Vishakhapatnam have used their natural landscape to form naturalistic moats. There are examples of new zoos, located away from cities, being developed with large naturalistic enclosures at Andaman & Nicobar Islands (Biological Park, Chidiyatapu), Rajasthan (Nahargarh Biological Park, Jaipur), Gujarat (Rajkot Zoo and Nature Park, Surat) and Maharashtra (Rajiv Gandhi Zoological Park, Pune).

Caged enclosure are being replaced to open moated enclosure at Kamla Nehru Zoo, Ahmedabad

Naturalistic enclosure for Sambar at Rajiv Gandhi Zoo, Pune

2.1.3 Naturalistic Moats

The word 'moat' was adapted in middle english from the French *motte* "mound, hillock" and was first applied to the central mound on which a fortification was erected, and then came to be applied to the excavated ring, a "dry moat". The term *moat* is also applied to natural formations reminiscent of the artificial structure.

Moated enclosure for Gaur at Indira Gandhi Zoological Park at Vishakhapatnam

The use of Moats rather than fences to separate animals from visitors in many modern zoos has been quite popular. The structure, with a vertical outer retaining wall rising directly from the moat, is an extended usage of the ha-ha of English landscape gardening.

Moats sometimes are being used as "wet moat" depnding upon the behaviour of animal to be housed therein. Such moat are being used to prevent them from swimming across. The practice of displaying in different kind of moats depends upon the "nature of the animal" unless they specifically affect barrier design. For example the macaques are excellent

Wet moat enclosure for tigers at Nehru Zoological Park, Hyderabad

swimmers while langurs are not and that tiger like to bathe and lions do not are useful in barrier design.

Within the range of moat structures that can be constructed, naturalistic moats are preferred as they look less engineered and resemble the animal's habitat. Over the years the zoos at Delhi, Chhatbir (near Chandigarh), Hyderabad, Bhubaneshwar, Chennai, Vishakhapatnam and Tirupati have constructed large moated naturalistic enclosures as space is not a constraint for them.

The disadvantage of using the wet moat is that due to non frequent removal of the water in moats invites many water borne diseases in the zoos. As well as creating moated enclosure in the flat land requires huge excavation of earth fill and high cost incurred on their creation.

2.1.4 Hidden Barriers

The great advantage of a hidden barrier is that by making it impossible, or at least difficult, for visitors to determine exactly what the physical limits of the animal's area are, a greater excitement can be generated with deeper sense of being part of the animal's world. Barriers can be disguised as a natural feature like a stream, a rock outcrop, eroded bank of a river edge and so on to screen unwanted views such as the Elephant enclosure and Pelican exhibit at Vishakhapatnam Zoo, Bear enclosure at Tirupati Zoo and Chimpanzee enclosure at Hyderabad Zoo. Fences hidden in depressed landforms and streams and water bodies appropriate to the exhibit can also create an illusion of freedom while protecting viewer from the animal and just as importantly, the animal from the viewer.

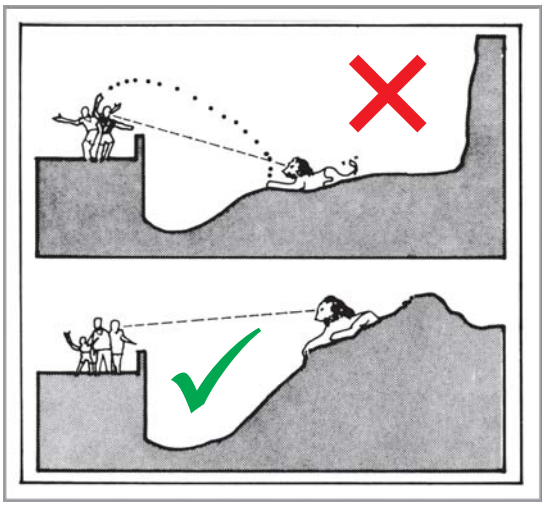
Chimpanzee enclosure at Nehru Zoological Park, Hyderabad

Older zoos, however, have to make do with conventionally constructed moats until such time that new exhibits can be constructed. In such zoos, it is recommended that linear plantings in the form of natural (not shaped) hedges be used to keep visitors back from the physical barrier of an animal exhibit. The plantings themselves will need to be protected from being trampled over enthusiastic visitors, with kick rails or hand rails. Additionally, creepers and climbers that hang down over the moat wall can be effectively used to hide the large expanses of concrete in such zoos.

2.1.5 Respecting the Animal

The saying that we "look down on what we despise, and look up to what we admire" is a metaphor which may be literally true in zoo exhibitory. Older exhibits in zoos around the world routinely placed dangerous animals in a visual pit. Such exhibits only encouraged visitors to view the animal with contempt and fear and at worst throw objects or poke sticks at it. Animal exhibit areas should be designed along with the barriers to place the animal either at or above human eye-level. This makes exhibit more interesting and impressive to the viewer, as the animal is respected. Animals placed above the viewers may also experience less stress.

Viewing animals at human eye level in Nehru Zoological Park, Hyderabad



2.1.6 Controlled Viewing

Animal exhibit areas and barriers should be designed in such a way that cross views of other people are avoided. The undesirable aspect of 360 degree viewing, common

Illustration showing to allow the animal to move through the view areas

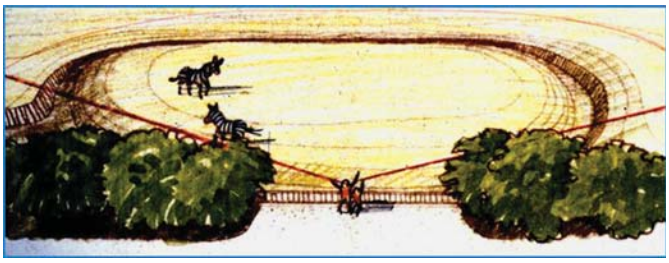


Illustration showing not to allow entire exhibit to be seen areas

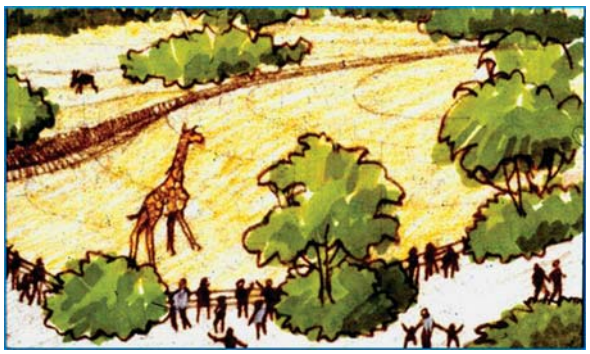


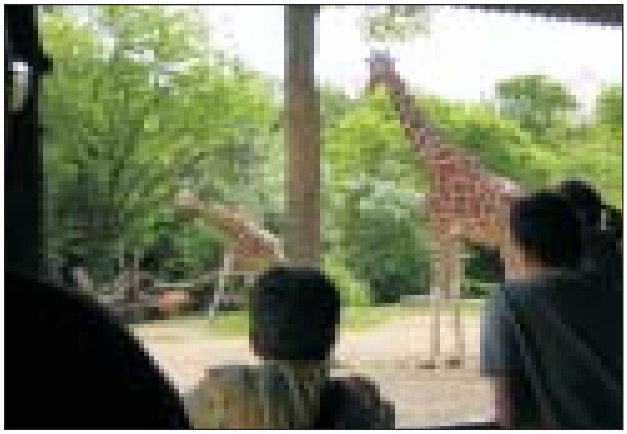
Illustration showing breakup viewers into the smaller groups

in many older zoos is that animal is placed as if in a circus surrounded by people. This lets the visitors concentrate on each other rather than spend time viewing the animal. This implicitly encourages a greater disrespect for the animal.

Viewing locations and barriers should also ensure that visitors cannot see entire exhibit areas from any one point or from all points (360 degree viewing) as has been done at many of the Indian zoos. Such viewing makes the visitor lose interest very quickly in the exhibit. In such scenario the animal becomes a part of a park background rather than attracting focused attention.

Wherever possible, a greater number of viewing points or viewing windows should be planned to give the visitors special views of the animals. In the case of certain animals e.g. lions and tigers, where visitors are bound to congregate, the length of viewing area can be divided in a way to increase the viewing opportunities for visitors.

2.1.7 Viewing "Hides" or "Blinds"



Viewing hide structure at Giraffe enclosure at Melbourne Zoo, Australia

It is also important that zoos should provide viewing for certain special exhibits through suitably designed "hides" or "blinds". These are covered shelters which penetrate perimeter barriers and allow viewing through glasss windows. Viewing "hides" which will provide more intimate viewing as has been done with the underwater otter viewing at Hyderabad, Himalayan newt exhibit at Padmaja Naidu Himalayan Zoological Park at Darjeeling, turtle enclosures at Madras Crocodile Bank Trust, Mammalapuram and Gharial exhibit at Nadankanan Zoo, Bhubaneshwar. They also provide shelter for visitors and contain interpretive material about the animals and their habitat.

2.1.8 Tree Protection

While designing new natural habitat zoo enclosures on undisturbed natural sites, it is desirable that the areas remain as undisturbed a possible. Animals should be located in areas of the site that most closely resemble their natural habitats, depending on the openness or density of the existing forest cover, so that minimal modifications will be necessary. To achieve this end as many mature trees as possible should be retained, as for most species forested areas are needed to display their natural habitat. These existing trees should be protected from animal browsing and debarking, either individually, or in large enclosed areas, by a variety of techniques including fences, wire mesh trunk wrapping or photo-voltaic solar fencing .

Protecting tree cover from animals at Melbourne Zoo

Use of chainlink mess around tree stem to protect from debarking at Rajiv Gandhi Zoo, Pune

2.1.9 Netted Aviaries

In a bird aviary the barrier is the entire structure itself. Rigid structure aviaries have been constructed in zoos for decades and such old structures actually resemble animal cages. However such aviaries are expensive due to the cost of the steel and are limited in their use as structural considerations make them fairly limited in size. Netted aviaries by comparison can be made substantially bigger in size due to their much lighter weight. Such aviaries have been used successfully in progressive zoos around the world and in India the rigid iron bar aviaries at Vandalur and Lucknow zoos have been replaced by large-open netted aviaries.

Aviary at Nandankanan Zoological Park, Bhubaneshwar

These types of structures are also suitable for smaller species that are also excellent leapers and climbers such as small to medium sized cats and primates, squirrels, martens and similar animal species.

Aviary for Pelicans at Indira Gandhi Zoological Park at Vishakhapatnam.

2.1.10 Piano wire

Stretched vertical wires can be very effectively used for bird aviaries & housing small mammals and large reptiles with no visual obstruction. Though this has been used in many countries, so far no zoo in India has tried this. This can be encouraged.

2.1.11 Glass barrier

Good quality and tough glass sheets and of different shapes are now available. They can be very effectively used as barrier. Of course glass have been used in limited scale, as viewing windows in wall/mesh barriers in India. They are widely used in reptile (snake) enclosures and aquarium.

Using glass as a barrier at tiger exhibit in Disney Animal Kingdom, Orlando, USA.

2.1.12 Use of Stainless steel / aluminum

As chain link mesh or welded mesh tend to rust and have short life span, stainless steel can replace them slowly even as supporting members like posts, trusses, pipes and other members. Aluminum also can be used in limited scale, where great strength is not required. These two materials shall be particularly ideal for areas with high salinity and humidity.

2.1.13 Barriers in Off Exhibit Areas

Barriers located in areas not visible to the public must provide adequate safety to zoo staff and animals, but these barriers are purely functional.

Some suggestion about use of different material for barriers of different species as suggested by a committee of experts is appended to the manual.

The vultures housed in off - exhibit at Conservation Breeding Centre for Vultures at Pinjore are provided with bamboo screening as a barrier.

2.2 Summary of Barrier Types

In general, the animal species, it's danger to human beings if loose, and it's ability or inability to jump or climb determines the physical barrier. No single barrier type meets all needs. Thus a coordinated system of barriers should be provided.

Primary Barriers – These provide safe physical containment for the animals both on and off-exhibit in areas used by the animals on a regular basis. Examples include perimeter barriers for display and off-display enclosures, paddocks, night rooms or retiring dens and raceways.

Secondary Barriers – These areas provide temporary physical animal containment should the animals escape from primary barriers and keep visitors from contacting animals. Examples include vestibules in animal enclosures, safety partitions to prevent "blind spots" in holding areas and fencing to keep visitors from entering off-display areas and rail or other barriers to keep visitors away from hazardous areas like moats or primary fencing barriers. The zoo's perimeter fence is also a type of secondary barrier.

Tertiary Barriers – These are intended to keep animals out of planted areas or away from primary barriers and often use "hot" or electrified wires disguised as natural features such as "hot grass", "hot vines", "hot roots", etc.

Electrified barriers (photo voltaic powered fence/power fence) may be used to increase the effectiveness of primary barriers (such as placing electrified wires on hidden fencing or along moats to discourage climbing or swimming. However electrified barriers may become unreliable and must not be used as primary barriers by themselves.

Exceptions and Exemptions – Since the barrier types listed may not be necessary or appropriate in all cases and to encourage innovation and advancement:

2.2.1 Physical Barrier and their Types

Physical barriers are used to prevent the animal from escaping as well as to discourage or prevent visitors from attempting to enter the exhibit.

Barrier Type	Advantages	Disadvantages
Moats – u-shaped (vertical sides)	• No contact with animals. • Less chances of transmission of infectious disease from visitors.	• Needs large areas. • Improper drainage can lead to proliferation of parasitic load. • Structural design makes these very expensive to build. • Animals can fall into moat areas hurting themselves.
Moats – v-shaped (sloped sides)	• Reduced contact with animals • Less expensive to build than • U-shaped moats. • More natural looking than • U-shaped moats.	• Needs large areas. • Improper drainage can lead to proliferation of parasitic load. • Animals can walk into moat areas making them less visible to visitors.
Fences – chain-link, welded wire mesh	• Requires much smaller area than moats. • Inexpensive to build • Can be hidden easily with vegetation.	• Visitor vandalism. • High maintenance. • Clear viewing requires expensive glass viewing areas.
Glass – laminated tempered	• Close visual connection between visitors and animals. • Provides privacy to animals by insulating from noise. • Requires much smaller area than moats.	• Reflection of light. • Off glass surfaces reduces visibility. • Frequent cleaning required. • Expensive to construct and replace. • Visitor vandalism
Low walls to simulate clay banks	• Natural looking. • Enrichment possibilities. • Nocturnal animal and reptiles may use for clinging, hibernation, aestivation. • Requires much smaller area than moats	• Authentic looking clay banks can be expensive to construct.
High walls to simulate rock cliffs	• Natural looking. • Requires much smaller area than moats	• Authentic looking rock cliffs can be very expensive to construct. • Unrealistic rockwork detracts from exhibit.

2.2.2 Animal Types & Barrier Recommendations

Animal Type	Examples	Front barrier	Rear barrier
Terrestrial species / jumping & climbing	Tiger, Asiatic lion	U-shaped dry or wet moats, glass viewing structures at special viewing areas	U-shaped dry moats OR high steel wire mesh fences OR high rock walls
Terrestrial species / jumping	Jackal, Wolf, Hyena	V-shaped (flat bottomed) dry moats with or without chain-link fences	V-shaped (flat bottomed) dry moats OR steel wire mesh fences
Arboreal species/ climbing	Himalayan Black Bear, Sloth Bear	U-shaped / V-shaped dry moats	U-shaped / V-shaped dry moats OR high smooth walls, OR overhanging rock walls
Arboreal species/ jumping & climbing	Monkeys, Lion-tailed macaque, Langur, Nilgiri langur	U-shaped / V-shaped dry moats, shallow wet moats, netted aviaries with glass viewing	U-shaped / V-shaped dry moats OR shallow wet moats, netted aviaries
Terrestrial species/ jumping	Blackbuck, Spotted deer, Barking deer, Sambar, Nilgai	V-shaped (flat bottomed) dry moats with or without chain-link fences	V-shaped (flat bottomed) dry moats OR steel wire mesh fences
Terrestrial/non–jumping	Gaur, Wild boar, Rhinoceros, Asian Elephant	V-shaped dry moats	V-shaped dry moats OR low walls (clay banks), cattle grids (gaur)
Aquatic & semi-aquatic species/ non-jumping	Hippopotamus, Crocodile, Otter	Wet moats (exhibit pools)	Low walls (clay banks)

2.2.3 Visitor Barrier Types

Barrier Type	Advantages	Disadvantages
Steel guardrail	• Long lasting. • Maintenance free if galvanized. • Safe-good for dangerous animal exhibits.	• Expensive to construct • Relatively unattractive to look at.
Hardwood guardrail	• Attractive to look at. • Fits most natural habitat themes. • Relatively safe - good for non-dangerous animal exhibits	• Expensive to construct with hardwood can rot in high humidity climates

Bamboo guardrail	• Attractive to look at – fits most natural habitat themes. • Inexpensive to construct.	• Relatively weak – should be used for non-critical areas. • Needs replacement every few years.
Eco-wud (wood substitute) guardrail	• Long lasting. • Maintenance free. • Cheaper than hardwood or steel. • Relatively safe – good for non-dangerous animal exhibits.	• More expensive than bamboo. • Appearance may not suit all theme areas.
Low hedge	• Attractive to look at. • Inexpensive to install. • Hedges can enclose a low fence.	• Not a real barrier – can be broken through easily. • Needs regular maintenance and protection from vandalism.
Nylon rope kick rail	• Very inexpensive to construct.	• Not a real barrier – should be used for landscape protection. • Needs replacement every few years.

2.2.4 Visual Amenities and Exhibit Viewing

Visual connections are being used to focus visitor's attention on special views into the exhibit including the animal and its immediate surroundings.

Barrier Type	Advantages	Disadvantages
Walls (brick, concrete)	• Long lasting. • Easy to construct.	• Expensive to construct. • Unattractive to look at unless hidden.
	• Maintenance free.	
Bamboo/ cane fences	• Attractive to look at. • Fits most natural habitat themes. • Inexpensive to construct. • Easy to install.	• Needs maintenance and protection from vandalism. • Replacement every few years.
Hedges	• Attractive to look at. • Inexpensive to plant.	• Needs regular maintenance and protection from vandalism.
Green walls (moss, creepers)	• Attractive to look at. • Fits most natural habitat themes from vandalism.	• Expensive to construct. • Needs maintenance and protection.
Artificial rockwork	• Attractive to look at. • Fits most natural habitat themes. • Long lasting. • Maintenance free.	• Very expensive to construct. • Needs specialized fabricators to obtain realistic results.

3.0 Barrier Analysis & Recommendations

3.1 Terrestrial species / jumping & climbing

3.1.1 Bengal tiger

Nature of the Animal

Bengal tiger are quite large and are slightly smaller than the Siberian tiger. It is well known, however, that animals that have been raised or even born in zoos often grow to be larger than animals ever do in the wild. Although they are called "Bengal tigers" in nearly every zoo, there is only a relative few whose pedigree is beyond doubt. However the genetic analysis of such individuals is underway by Laboratory for Conservation of Endangered Species (LaCONES), Hyderabad.

It must be mentioned that the tiger lives in humid evergreen forests, in dry open forests and in the grassy swamps of the *Terai* while in the Sunderbans it leads an almost amphibious life in mangrove forests, mud, swamp and brackish water.

Unlike many cats, tigers seem quite fond of water and are good swimmers. Tigers are mainly active at twilight or night, using their sight and sense of hearing rather than smell, to stalk their prey. In long grass the stripes on the tiger's coat break up its outline making it more difficult to spot. In other words it merges well with its surrounding.

Barrier Suggestions

a) In case of 'U' or 'V' type dry or wet moat, where there is sufficient land available, it is suggested to provide 7.5m top width and a depth of 5m including the parapet wall. The digramatic details on 'U' or 'V' type moats provided at page 21 and 22.

The present dimensions of moats of different zoos are as follows:

Analysis of Barrier Dimensions

BENGAL TIGER	Width (M)	Depth(M)/ Height(H)	Moat type
Indian Zoos:			
Nehru Zoological Park, Hyderabad	7.46	3.76	Wet
Indira Gandhi Zoo, Vishakhapatanam	9.0	5.0	Dry
Arignar Anna Zoological Park, Vandalur	12.0	8.0	Dry
Assam State Zoo, Guwahati	N. A.	6.0	Bar
National Zoological park, Delhi	8.71	4.4	Wet

S. V. Zoological Park, Tirupati	10	5.5	Dry
Foreign Zoos :			
Denver Zoo, Colorado, U.S.A.	7.6	5.5	Dry
Philadelphia Zoo, Philadelphia, U.S.A.	5.3	5.3	Dry
American Association of Zoo Association	–	5.0	–

N. A.: Not Available

b) Where tigers are needed to be kept in confined to chain link mesh the suggested dimension of the barrier is 5mm height fixed to 75mm x 75mm x 6mm angle iron posts. The dimension of the mesh shall be 5cm x 5cm x 8g. A barbed wire over hang of 0.5m is to be provided on the top with horizontal member in the middle of the post and the mesh should be fixed on the inner side of the enclosure.

c) The rear barrier can be of the type mentioned in (b) above or of brick or rock masonry of 5mt height.

Discussion

While lions should be housed in dry moated enclosures tigers can be provided with either wet or dry moats of 'U' or 'V' shape as they are good swimmers and love water. But wet moats are being discouraged as they breed parasites, need large quantities of water and the tigers drink the contaminated moat water.

- The parapet on moat wall should not be too thick for visitors to sit on this.
- Hanging creepers on parapet helps camouflage the wall.
- Well kept thick hedges with guard rails should be provided as buffers to prevent approach of visitors to the parapet and to camouflage the masonry. Chainlink mesh fixed below the guard-rail prevents visitors from crossing the hedge and go close to the parapet.
- Wall with large glass windows have been tried in many zoos abroad for providing close unhindered viewing. This is extremely popular.
- Heavy rock work used to camouflage night shelters creates problems for old and weak animals as they find it difficult to climb.
- Instead of using heavy rock work on the rear wall, that is expensive, rocky perches can be provided for use by animals with good effect.

3.1.2 Asiatic lion

Nature of the animal

The Asiatic lion is found in the Gir Forest of Gujarat only - a scrub-type deciduous forest with stunted teak trees, palas, jamun and ber and patches of small bamboo clumps and an undergrowth of thorny shrubs and bushes. Lions rest by the day and at dusk go in quest of their prey.

Barrier suggestions

a) In case of 'U' or 'V' type dry moat, where there is sufficient land is available, it is suggested to provide 7.5m top width and a depth of 5m including the parapet wall. Wet moat is not at all recommended as lions have been reported to have been drowned in moat water.

The present dimensions of moats of different zoos are as follows:

ASIATIC LION	Width (M)	Depth(M)/Height(H)	Moat type
Indian Zoos:			
Nehru Zoological Park, Hydrabad	10.44	4.17	Dry
Indira Gandhi Zoo, Vishakhapatnam	8.0	4.5	Wet
Arignar Anna Zoological Park, Vandalur	12.0	8.0	Dry
Assam State Zoo, Guwahati	9.14	4.57	Dry
Lucknow Zoological Park, Lucknow	16.0	8.0	Dry
Kanpur Zoo, Kanpur	17.0	12.0	Dry
Foreign Zoos :			
Denver Zoo	7.6	5.5	Dry
San Francisco Zoo	8.1	4.1	Dry
Philadelphia Zoo	7.6	5.3	Dry

b) Where lions are needed to be kept in confined to chain link mesh the suggested dimension of the barrier is 5mm in height fixed to 75mm x 75mm x 6mm angle iron posts. The dimension of the mesh shall be 5cm x 5cm x 8g. A barbed wire over hang of 0.5m is to be provided on the top with horizontal member in the middle of the post and the mesh should be fixed on the inner side of the enclosure.

c) The rear barrier can be of the type mentioned in (b) above or of brick or rock masonry of 5mt height.

3.1.3 Barrier Recommendations & Comments

The recommended front barrier design for tigers is a U-shaped wet moat as the animal is almost amphibious in nature. The moat "V type" should have a sloped inner wall so that the animal can walk down to the water.

The recommended barrier design for Asiatic lions is a U-shaped dry moat as the Asiatic lions are found in the dry deciduous Gir Forest and are not necessarily seen near water. The moat should have a sloped inner wall in a way that the animal can not walk or hide into the moat.

Dry moat enclosure for lions

If space for a moat is not available all around the exhibit then the recommended rear barrier design for Asiatic lions and tigers is high chain link fences or high rock walls. Both must be designed by qualified structural engineers. The advantage of a chain link fence over a wall is that it can be painted a dull green or black colour and hidden easily in the shadows created by dense vegetation behind (outside) the fence. The bamboo inside the fence to screen could also be used.

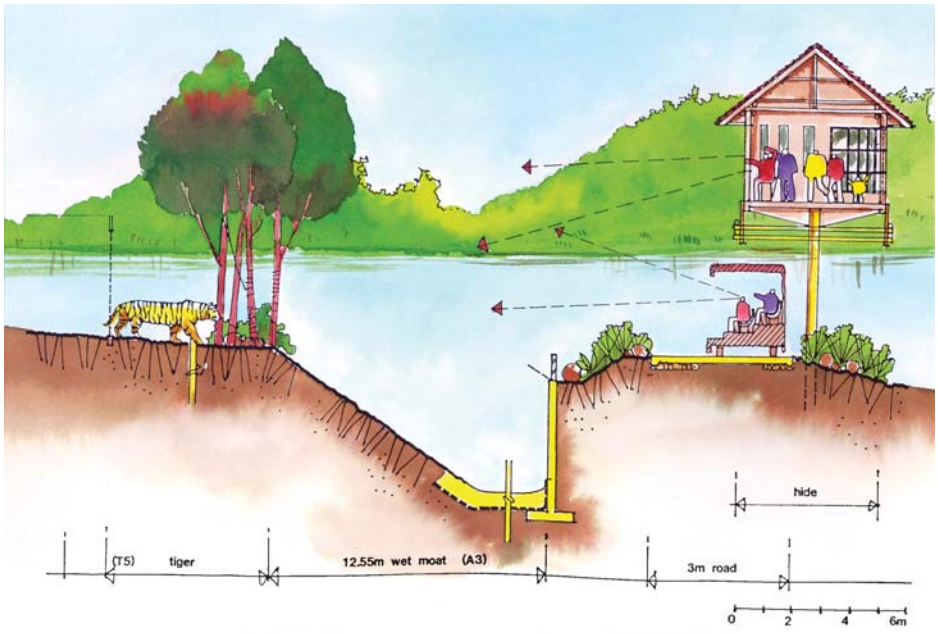


Illustration showing 'V' shape dry moat exhibit for tigers with elevated and tram viewing.

The Hyderabad Zoo has successfully used creepers (climbers) planted to hang over the moat wall to cover and camouflage it. Slender species of creepers can also be planted on mesh fence

The Vandalur Zoo is of the opinion that the plant hedges in front of the moat do not always work as a people barrier especially in high visitation (popular animal) areas as the hedges are broken through easily by visitors.

Planted vegetation buffers are highly recommended for such exhibits as a way of keeping visitors from looking over the moat wall but these buffers must be protected themselves from visitors by continuous guard rails or fencing hidden in vegetation.

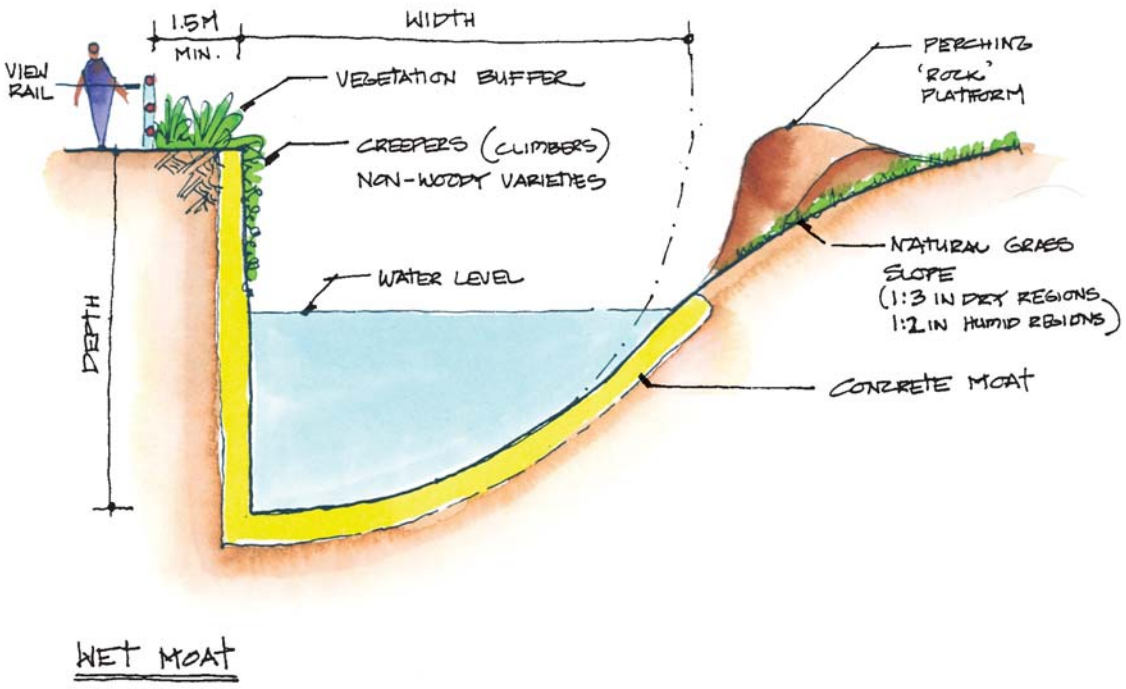
Specially constructed viewing shelters with laminated tempered glass have been used in conjunction with fence/wall barriers successfully for lion and tiger exhibits in zoos around the world. These viewing areas are extremely popular with visitors as they allow an uninterrupted close up view of the animals.

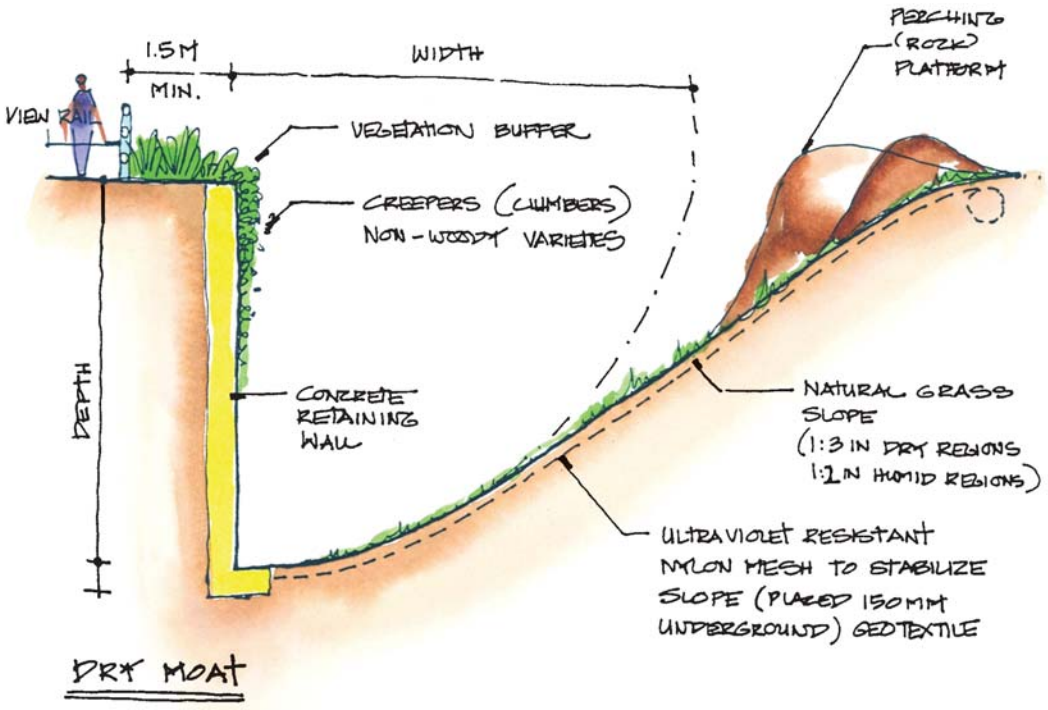
The Lucknow Zoo is of the opinion that too muck rock work used as a rear barrier or inside the exhibit creates difficulties for weak/ill animals in climbing and returning to feeding and retiring cubicles.

Due to its expense, rockwork is only recommended for creating rock perches which allow visitors to see lions more clearly as they rest in the sun. Rear walls covered with rockwork are expensive and difficult to construct in a realistic manner and so should only be used if moats and fences are unavailable as options.

3.1.4 Schematic Barrier diagrams

PHYSICAL BARRIER TYPES Asiatic Lion, Bengal Tiger





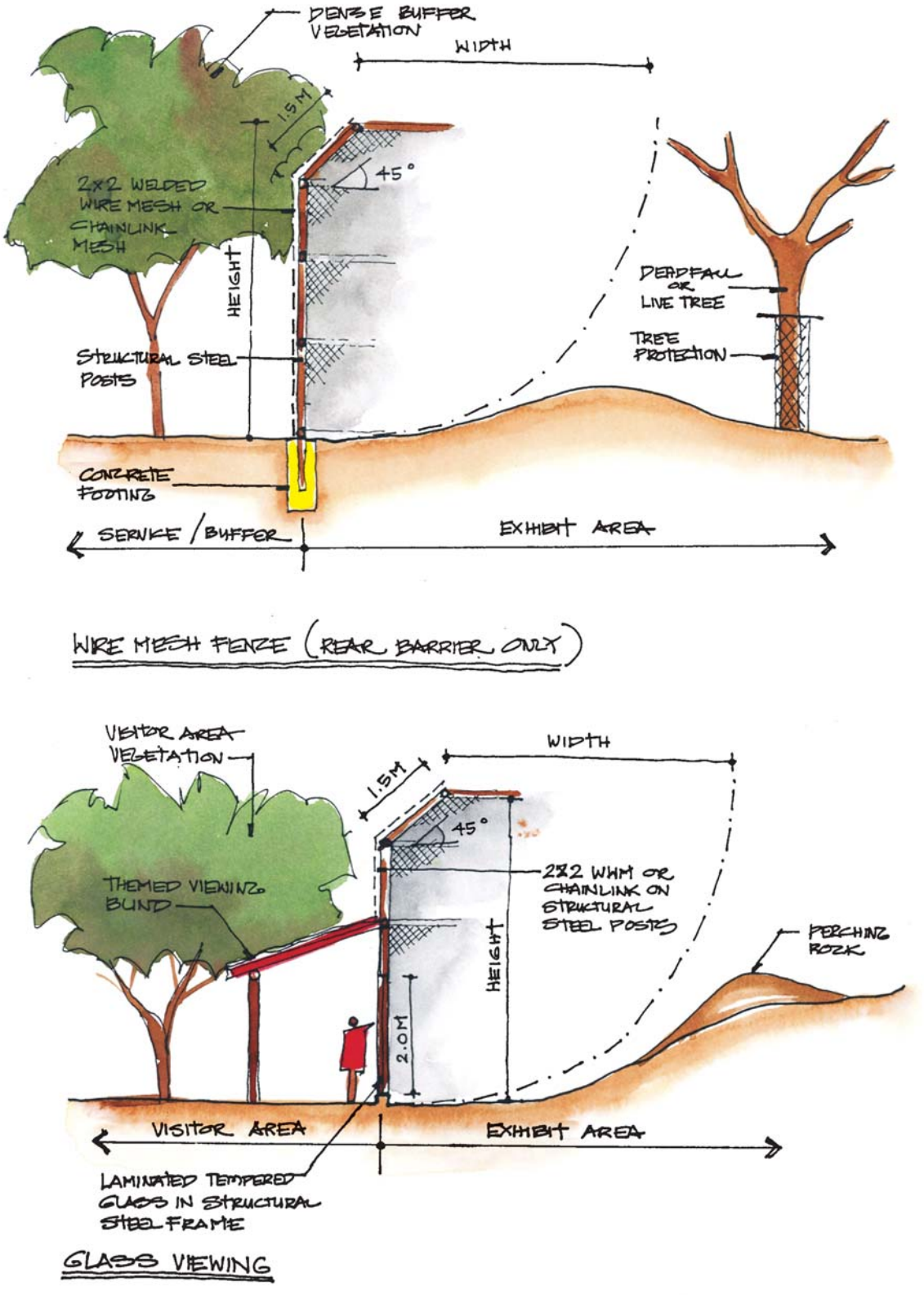


Illustration showing the use of inward incliend overhang with glass viewing for large carnivores.

3.2 Terrestrial species – jumping

3.2.1 Jackal

Nature of the animal

The jackal is a member of the Dog family or *Canidae* and has many attributes. They have a well-organized social life and have strong family bonds between father, mother and pups. This is seen even under captive conditions.

The Jackal inhabits forests, the countryside, dry open plains and deserts. They can also be found at higher altitudes in the Himalayan foot hills as well as other hilly regions. They usually come out at dusk and retire at dawn.

Analysis of Barrier Dimensions

JACKAL	Width (M)	Depth(M)/Height(H)	Moat type
Indian Zoos:			
Nehru Zoological Park, Hyderabad	4.0	2.8	Dry
Indira Gandhi Zoo, Vishakhapatnam	3.0	2.6	Dry
Arignar Anna Zoological Park, Vandalur	3.0	2.6	Dry
S. V. Zoological Park, Tirupati	4.0	3.0	Dry
Lucknow Zoological Park, Lucknow	N. A.	3.0	Dry
Kanpur Zoological Park, Kanpur	N. A.	3.0	Chain link

N.A.: Not Available

Barrier suggestions

a) It is suggested that a dry moat of 3.5m width and 2.5m depth can be provided for them. The analysis of dimensions of barrier in various Indian Zoos is given in the following table.

b) The rear barrier can be of wall of 2.5m height or of 3.0m chain link mesh of 5cmx5cmx10g.

c) In case of space constraint, the viewers' side can have 3.0m chain link mesh fence of the above specification. The use of small opening (too small for feet) discourages climbing.

3.2.2 Wolf

Nature of the Animal

The Indian wolf is almost the size of an Alsatian dog. With its long legs it can run great distances and it has powerful jaws to seize its prey. Wolves live in open country and forests, hunting by day and hiding by night under fallen trees, among rocks or in holes dug in the ground. Because they hunt animals larger than themselves, wolves hunt in packs numbering 20-40 individuals.

Barrier Suggestions

a) It is suggested that a dry moat of 3.5m width and 2.5m depth can be provided for them. The dimensions of barrier of Indian Zoos is given in the following table.

Analysis of Barrier Dimensions

INDIAN WOLF	Width (M)	Depth(M)/Height(H)	Moat type
Indian Zoos:			
Nehru Zoological Park, Hyderabad	4.6	3.25	Dry
I. G. Zoological Park, Vishakhapatnam	4.0	2.5	Dry
Arignar Anna Zoological Park, Vandalur	3.3	2.7	Dry
Gandhi Zoo, Gwalior	N. A.	2.5	Dry
Nature Park, Surat	6.0		Dry
S. V. Zoological Park, Tirupati	4.0	3.15	Dry
Lucknow Zoological Park, Lucknow		3.0	Dry
Foreign Zoos :			
West Berlin Zoo (Intl. Zy. Bk.14)	4.0	N.A.	–
Night Safari, Singapore	5.0	2.5	Wet
Frankfurt Zoo (Intl. Zy. Bk. 11)	3.3	3.1	–
Australia (NSW)	2.4	3.5	–

N. A. – Not Available

b) The rear barrier can be of wall of 2.5m height or of 3.0m chain link mesh of 5cmx5cmx10g.

c) In case of space constraint, the viewers' side can have 3.0m chain link mesh fence of the above specification.

3.2.3 Hyena

Nature of the animal

The Striped hyena is distinguished from the other African and South West Asian hyena species by the dark stripes on its grey or yellowish grey body and by an erentile mane around its neck and shoulders that extends down the middle of its back.. The Striped hyena is abundant in the bare, plains, deserts, rocky scrub –covered hills, grass and open jungle. They may lie concealed by day in high grass, under bushes or in cane fields, but the den usually preferred in a cave amongst rocks, or a hole dug in the side of a hill.

Analysis of Barrier Dimensions

STRIPED HYENA	Width (M)	Depth(M)/Height(H)	Moat type
Indian Zoos:			
Nehru Zoological Park, Hyderabad	N. A.	2.1	Dry
Indira Gandhi Zoo, Vishakhapatnam	5.0	3.0	Dry
Arignar Anna Zoological Park, Vandalur	3.3	2.2	Dry
Assam State Zoo, Guwahati	N. A.	2.55	Dry
Gandhi Zoo, Gwalior	N. A.	2.0	Dry
Nature Park, Surat	6.0		Dry
S. V. Zoological Park, Tirupati	6.0	3.0	Dry
Lucknow Zoological Park, Lucknow	N. A.	2.5	chain link
Kanpur Zoological Park, Kanpur	5.0	3.0	–
Foreign Zoos :			
Night Safari, Singapore	5.0	NA	–

N. A. - Not Available

Barrier Suggestions

a) It is suggested that a dry moat of 3.5m width and 2.5m depth can be provided for them. The dimensions of barrier of Indian Zoos is given in the table at page 25.

b) The rear barrier can be of wall of 2.5m height or of 3.0m chain link mesh of 5cmx5cmx10g.

c) In case of space constraint, the viewers' side can have 3.0m chain link mesh fence of the above specification.

3.2.4 Blackbuck

Nature of the Animal

The Blackbuck is the sole representative in India of the genus *Antelope.* The Blackbuck used to occur in practically all the plains areas except along the Indian coast southward from the neighborhood of Surat. They avoid forest or hill tracts.

They feed on grass, leaves, pods of *Acacia* etc. and various cereal crops. When alarmed, the group moves off in a series of leaps and bounds, finally braking into gallop.

Analysis of Barrier Dimensions

BLACKBUCK	Width (M)	Depth (M)/ Height (H)	Moat Type
Nehru Zoological Park, Hyderabad	5.0	5.0	Dry
Indira Gandhi Zoo, Vishakhapatnam	5.5	2.5	Dry
Arignar Anna Zoological Park, Vandalur	2.5	2.3	Dry
Nature Park, Surat	3.5	2.1	Dry
National Zoological Park, Delhi	5.76	2.56	Dry
S. V. Zoological Park, Tirupati	6.0	2.1	Dry
Lucknow Zoological Park, Lucknow	NA	1.1	Dry*
Kanpur Zoological Park, Kanpur	4.0	1.5	Dry*
Foreign Zoo :			
Frankfurt (Intl. Zy. Bk. 11)	4.5	1.7	–

* Overhang of 1.5 m is part of the barrier
** Overhang of 1.75 m is part of the barrier
N. A. – Not Available

Barrier Suggestions

a) It is suggested that a dry moat of 3.5m width and 2.5m depth can be provided for them. The dimensions of barrier of Indian Zoos are given in the table at page 26.

b) The rear barrier can be of wall of 2.5m height or of 3.0m chain link mesh of 7.5cmx7.5cmx10g.

c) In case of space constraint, the viewers' side can have 3.0m chain link mesh fence of the above specification.

3.2.5 Barking Deer

Nature of the Animal

The Barking Deer is a relatively small animal with a shoulder height of 25 to 30 inches and length not exceeding 30 inches. It is both diurnal and crepuscular. Barking deer keep to more or less thick jungle and come out to graze in the outskirts of forest or in pen clearings. They are fairly diurnal in habit. The food consists of various leaves and grasses and wild fruits.

Analysis of Barrier Dimensions

BARKING DEER	Width (M)	Depth (M) /Height (H)	Moat Type
Indian Zoos:			
Nehru Zoological Park, Hyderabad	N.A	N.A	Dry
Indira Gandhi Zoo, Vishakhapatnam	6.0	2.0	Dry
Arignar Anna Zoological Park, Vandalur	2.5	2.3	Dry
National Zoological Park, Delhi	4.77	2.32	Dry
Lucknow Zoological Park, Lucknow	–	2.5	Dry*

*Overhang is part of the barrier
N. A. – Not Available

Note: The Detroit Zoo in U.S.A. has barrier of 6.7m Wide x 2.8 m Height

Barrier Suggestions

a) It is suggested that a dry moat of 3.5m width and 2.5m depth can be provided for them. The dimensions of barrier of Indian Zoos is given in the above table.

b) The rear barrier can be of wall of 2.5m height or of 3.0m chain link mesh of 7.5cmx7.5cmx10g.

c) In case of space constraint, the viewers' side can have 3.0m chain link mesh fence of the above specification.

3.2.6 Spotted Deer

Nature of the Animal

The Spotted Deer is seen in herds of ten to thirty, which may contain two or three stags. They are less nocturnal than Sambar and fed till late in the morning and again in the afternoon, and lie down in the interval in some shaped spot. Chital are prolific breeders; an interval of six months may see the production of new family.

Analysis of Barrier Dimensions

SPOTTED DEER	Width (M)	Depth(M)/Height(H)	Moat type
Indian Zoos:			
Nehru Zoological Park, Hyderabad	N. A.	1.6	Dry
Indira Gandhi Zoo, Vishakhapatnam	5.5	1.5	Dry
Arignar Anna Zoological Park, Vandalur	N. A.	N. A.	Dry
National Zoological Park, Delhi	6.35	2.56	Dry
S. V. Zoological Park, Tirupati	7.0	2.4	Dry
Lucknow Zoological Park, Lucknow	N. A.	2.0	Dry*
Kanpur Zoological Park, Kanpur	N. A.	2.0	Dry**
Foreign Zoos :			
Night Safari, Singapore	4.0	N. A.	Dry

*Overhang of 1.5 M is part of the barrier
**Overhang of 1.5 M is part of the barrier
N. A.– Not Available

Barrier Suggestions

a) It is suggested that a dry moat of 3.5m width and 2.5m depth can be provided for them. The dimensions of barrier of Indian Zoos is given in the above table.

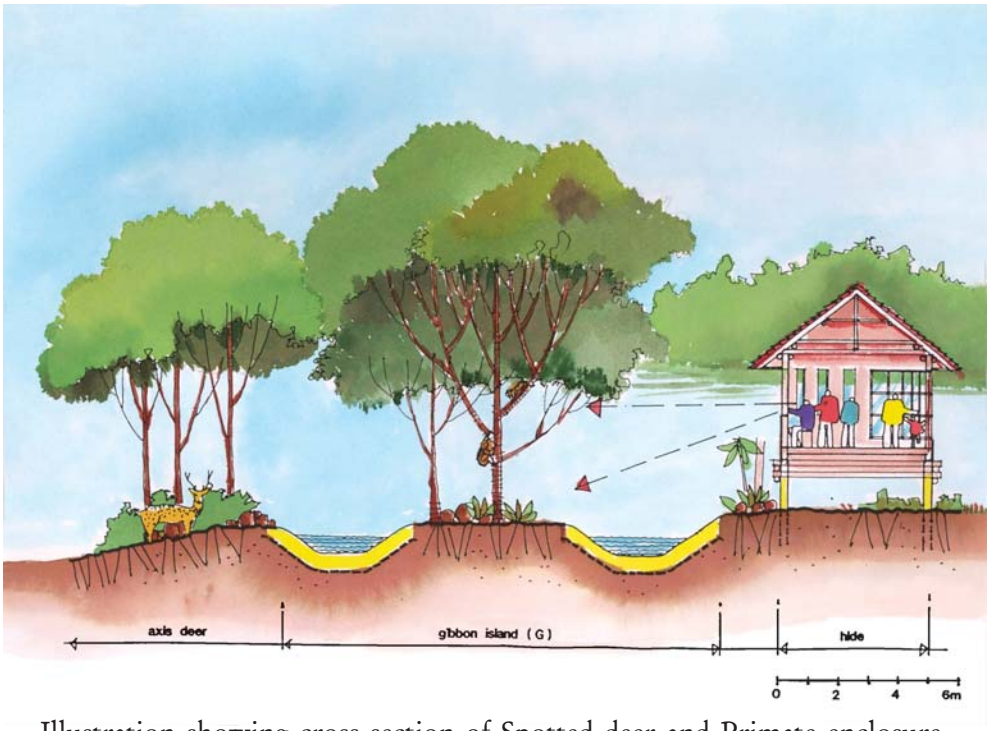


Illustration showing cross section of Spotted deer and Primate enclosure.

b) The rear barrier can be of wall of 2.5m height or of 3.0m chain link mesh of 7. 5cmx7.5cmx10g.

c) In case of space constraint, the viewers' side can have 3.0m chain link mesh fence of the above specification.

3.2.7 Sambar/Swamp deer/Sangai

Nature of the Animal

The Sambar is the largest Indian deer and carries the grandest horns, height at shoulder is nearly 150 cm. The average is about 140 cm. They are found in the forested hillsides, preferably near cultivation, their food consists of grass, leaves and various kinds of wild fruit. They feed mainly at night and retire into heavy cover at daybreak and do not usually come out till dusk. Sambar takes to water readily and swims with the body submerged. Only the face and antlers are seen above the water surface. They are fond of wallowing in mud. The males fight for territory.

The hard footed Barasinga (Swamp deer) and Sangai (Brow antlered deer) though belong to completely different habitats of Central India and floating vegetation of Loktak lake in Manipur can also be housed in similar exhibits like Sambar.

Analysis of Barrier Dimensions

SAMBAR	Width (M)	Depth(M)/Height(H)	Moat type
Indian Zoos:			
Nehru Zoological Park, Hyderabad	N.A	1.6	Dry
Indira Gandhi Zoo, Vishakhapatnam	3.0	2.0	Dry
Arignar Anna Zoological Park, Vandalur	N.A	N.A	Dry
Assam State Zoo, Guwahati	N.A	3.0	Dry
Biological Park, A & N Islands	N.A	NA	Dry
National Zoological Park, Delhi	4.47	2.32	Dry
S. V. Zoological Park, Tirupati	7.0	2.0	Dry
Lucknow Zoological Park, Lucknow	25	2.5	Dry*
Foreign Zoos :			
Night Safari, Singapore	2.5	N.A	Dry

*Overhang of 1.2 M is part of the barrier
N.A. – Not Available

Note: The Detroit Zoo in U.S.A. has been using 6.7m W x 2.8m H barrier

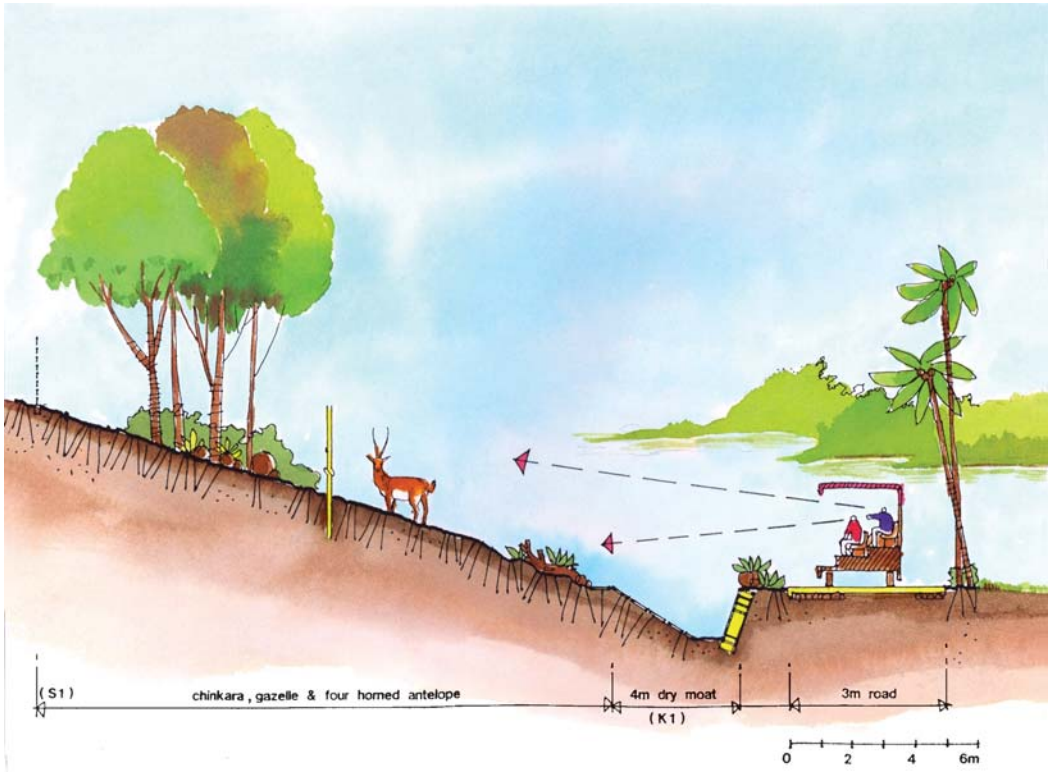


Illustration showing cross section of enclosure used for Chinkara and Four-horned antelope.

Barrier Suggestions

a) It is suggested that a dry moat of 3.5m width and 2.5m depth can be provided for them. The dimensions of barrier of Indian Zoos is given in the table at page 30.

b) The rear barrier can be of wall of 2.5m height or of 3.0m chain link mesh of 7. 5 cm x 7.5 cm x 10g.

c) In case of space constraint, the viewers' side can have 3.0m chain link mesh fence of the above specification

3.2.8 Nilgai

Nature of the Animal

The Nilgai is found only in the Indian peninsula from the base of Himalayas to Mysore. It does not occur in eastern Bengal, or Assam, or on the Malabar Coast.

Nilgai avoid dense forests. Their usual haunts are hills sparsely dotted with trees or level or undulating plains covered with a grass and patches of scrub. They freely enter cultivation and are a source of damage of crops. They feed till late in the morning and again early in the evening, caring little about the sun, seeking the shade only during the hottest hours of the day. They both graze and browse, feeding on the leaves and the fruit of the Ber *(Zizyphus sps.)* and other trees. The females and their young live in herd of 5-10 and always use the same places for resting and drinking within their home ranges. The adult bulls may be solitary or live in small groups.

NILGAI	Width (M)	Depth (M)/Height (H)	Moat type
Indian Zoos:			
Nehru Zoological Park, Hyderabad	4.0	2.4	Wet
Indira Gandhi Zoo, Vishakhapatnam	5.0	1.8	Dry
Arignar Anna Zoological Park, Vandalur	N.A.	N.A.	Dry
Assam State Zoo, Guwahati	N.A.	2.5	Dry
National Zoological Park, Delhi	6.14	2.56	Dry
S. V. Zoological Park, Tirupati	7.0	2.0	Dry
Lucknow Zoological Park, Lucknow	5.0	2.5	Dry

N. A. – Not Available

Barrier Suggestions

a) It is suggested that a dry moat of 3.5m width and 2.5m depth can be provided for them. The dimensions of barrier of Indian Zoos is given in the table at page 31.

b) The rear barrier can be of wall of 2.5m height or of 3.0m chain link mesh of 7.5cmx7.5cmx10g.

c) In case of space constraint, the viewers' side can have 3.0m chain link mesh fence of the above specification.

3.2.9 Barrier Recommendations & Comments

The recommended front barrier design for the Canid family, hyenas, deer and antelope species is a V-shaped (flat bottomed) dry moat since all of these animals essentially inhabit drier environments, i.e. they are not closely associated with water/marshes. V-shaped moats are also more natural looking than U-shaped moats and cheaper to build and are therefore are desirable. The disadvantage of a V-shaped moat is that the animal can enter the moat making it less visible to visitors. This can be dealt with by providing enough enrichment within the habitat itself and by keeping the moat bottom free of grasses.

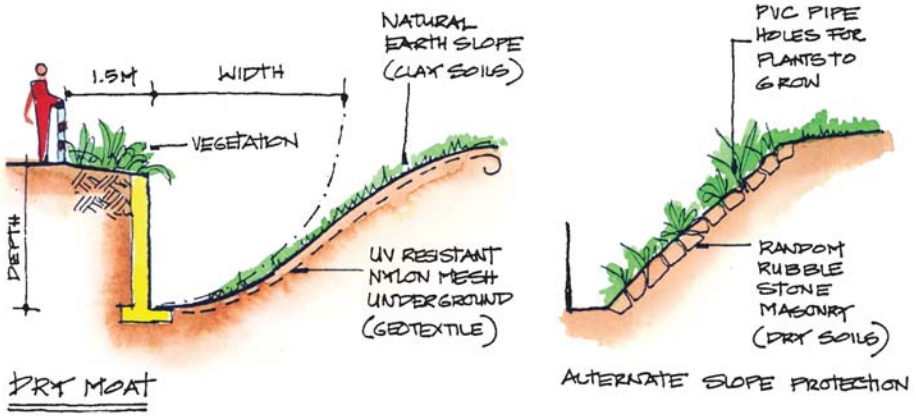
The Vandalur Zoo has observed that siltation of soil in moats during the rains reduces the barrier height giving these animals the chance to escape. Since siltation is created by erosion of unstable moat edges, these should be protected from erosion due to animal movement with underground mesh lining. In very dry regions the sloped edge may have to be constructed out of exposed random rubble stone masonry in which holes can be left for natural scrub vegetation to grow. This is more natural looking than concrete or plastered brick and therefore desirable.

If space is not available behind the exhibit then the recommended rear barrier design is a chain link fence, painted a dull green or black colour that can be hidden easily in the shadows created by dense vegetation behind (outside) the fence.

If space is available within the exhibit, the rear chain-link fence can be even more effectively hidden by means of a low 1 metre high fence in front which allows additional vegetation to be grown between the two fences to hide and shade the rear (barrier) fence. This method has effectively been used at the Pierre David deer exhibit at the Bronx Zoo.

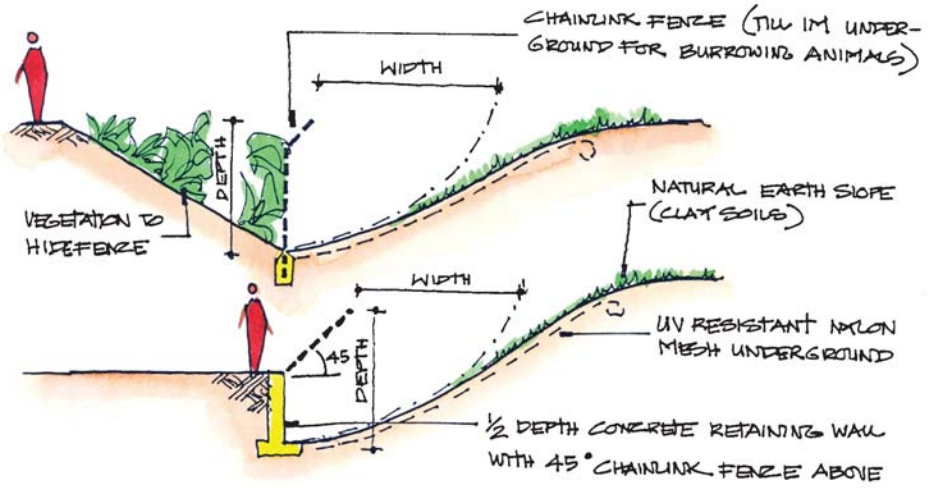
3.2.10 Schematic Barrier Diagrams

PHYSICAL BARRIER TYPES
Jackal, Wolf, Hyena, Blackbuck, Spotted Deer, Barking Deer, Sambar, Nilgai

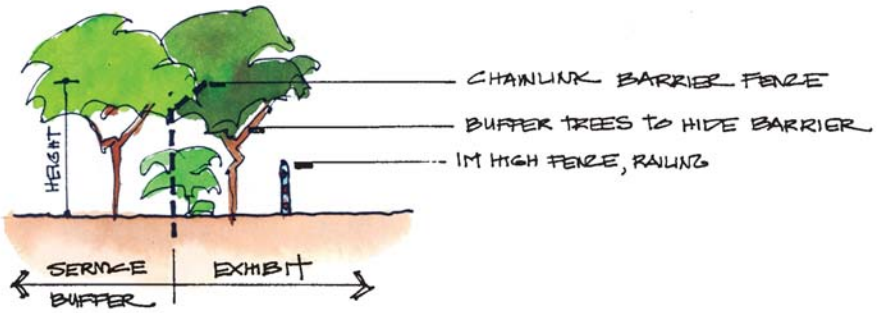


DRY MOAT

ALTERNATE SLOPE PROTECTION



DRY MOAT & FENCE OPTIONS



WIRE MESH FENCE (REAR BARRIER ONLY)

3.3 Arboreal species – climbing

3.3.1 Sloth bear/Sun bear

Sloth bears originally inhabited the deciduous monsoon forest and thorny jungles of India up to the Thar Desert in the west and the southern foot hills of the Himalayas in the North. It was also found in the rainforests and grassy forests of the Northeast. However, their range has considerably reduced. They do not only feed on fruits and berries but also roots, carcasses and many small animals including ants, termites and wild bees as well as honey. Their foraging activity, which begins at dusk, continues throughout the night and they take great pains to search food and even climb trees for its fruits and knocking down honeycombs. Though bulky, these bears have quick reflexes. They can dig for termites and climb on a tree for honey.

The Sloth bear is rather unusual among bears. The mobile lips form a tube through which it sucks up insects with a loud smuffing sound.

Analysis of Barrier Dimensions

SLOTH BEAR	Width (M)	Depth(M) /Height(H)	Moat type
Indian Zoos:			
Nehru Zoological Park, Hyderabad	3.58	2.08	Wet
Indira Gandhi Zoo, Vishakhapatnam	3.5	3	Dry
Arignar Anna Zoological Park, Vandalur	3.5	3.3	Dry
Assam State Zoo, Guwahati	N.A.	2.4	Dry
National Zoological Park, Delhi	3.4	3.4	Wet
S. V. Zoological Park, Tirupati	4.0	3.45	Dry
Lucknow Zoological Park, Lucknow	3.0	3.5	Wet
Kanpur Zoological Park, Kanpur	4.0	3.5	Dry
Foreign Zoos :			
San Francisco Zoo	2.6	2.2	Dry
Chicago Zoo	2.7	3	Dry
Berlin Zoo	3.7	3.4	Dry

N.A. – Not Available

Note: 1. Detroit Zoo in U.S.A. has Black bear enclosure with 4.5m W x 4m H barrier with overhang.
2. Australia (NSW) has provided 5.0m W x 4.2m H barrier.

Barrier Suggestions

i) It is suggested to provide 5.5m wide and 2.8m deep dry moats as front barrier. As moat on all sides is both expensive and takes a lot of space, the rear barrier can be 3.4m high smooth wall. The moat wall should be smoothly plastered.

ii) When there is shortage of space 3.5m chain link mesh of 5cmx5cmx12g with inclined steel plate of 1m on top can be provided.

iii) Alternatively the moated enclosure can have rear barrier of the type indicated in (ii).

3.3.2 Himalayan black bear/Himalayan or European brown bear

The Himalayan black bear has greatly elongated hair on the shoulders, sides of the throat and neck. Its fur is pitch-black, sometimes with a purple luster, and there is a large white mark on the chest, which is sometime Y-shaped. Himalayan black bears inhabit the steep forest hills of the Himalayas during summer, but in winter most of them come down to the lower valleys.

The food consumed by these bears varies with the season. In summer they live largely on wild fruits, berries and nuts of various kinds. During autumn ripening of corn or maize are raided. Insects are also part of their diet. There have been cases of human beings mauled or killed by these bears.

Analysis of Barrier Dimensions

HIMALAYAN BLACK BEAR	Width (M)	Depth(M) /Height(H)	Moat type
Indian Zoos:			
Nehru Zoological Park, Hyderabad	4.0	3.0	Wet
Indira Gandhi Zoo, Vishakhapatnam	3.5	3.0	Dry
Arignar Anna Zoological Park, Vandalur	4.5	3.1	–
Assam State Zoo, Guwahati	N.A.	3.5	–
National Zoological Park, Delhi	3.4	2.86	Wet
Lucknow Zoological Park, Lucknow	3.5	3.3	Wet
Kanpur Zoological Park, Kanpur	3.0	3.0	Dry
Foreign Zoos :			
London Zoo	3.2	2.9	–
Berlin Zoo	3.7	3.4	–
San Francisco Zoo	4.3	3.7	–

Note: 1. Detroit Zoo Black bear enclosure has 4.5m W x 4m H barrier with overhang.
2. Australia (NSW) has 5m W x 4.2m H barrier.

Though Himalayan or European brown bear are much larger than other two bears and live at much higher altitude in the Himalayas they can be kept in enclosures with similar barriers. However it will be better to keep them in moated exhibit wit wall on the rear.

Barrier Suggestions

i) It is suggested to provide 5.5m wide and 2.8m deep dry moats as front barrier. As moat on all sides is both expensive and takes a lot of space, the rear barrier can be 3.4m high smooth wall. The moat wall should be smooth a vehicle.

ii) When there is shortage of space 3.5m chain link mesh of 5cmx5cmx12g with inclined steel plate of 1m on top can be provided.

iii) Alternatively the moated enclosure can have rear barrier of the type indicated in (ii).

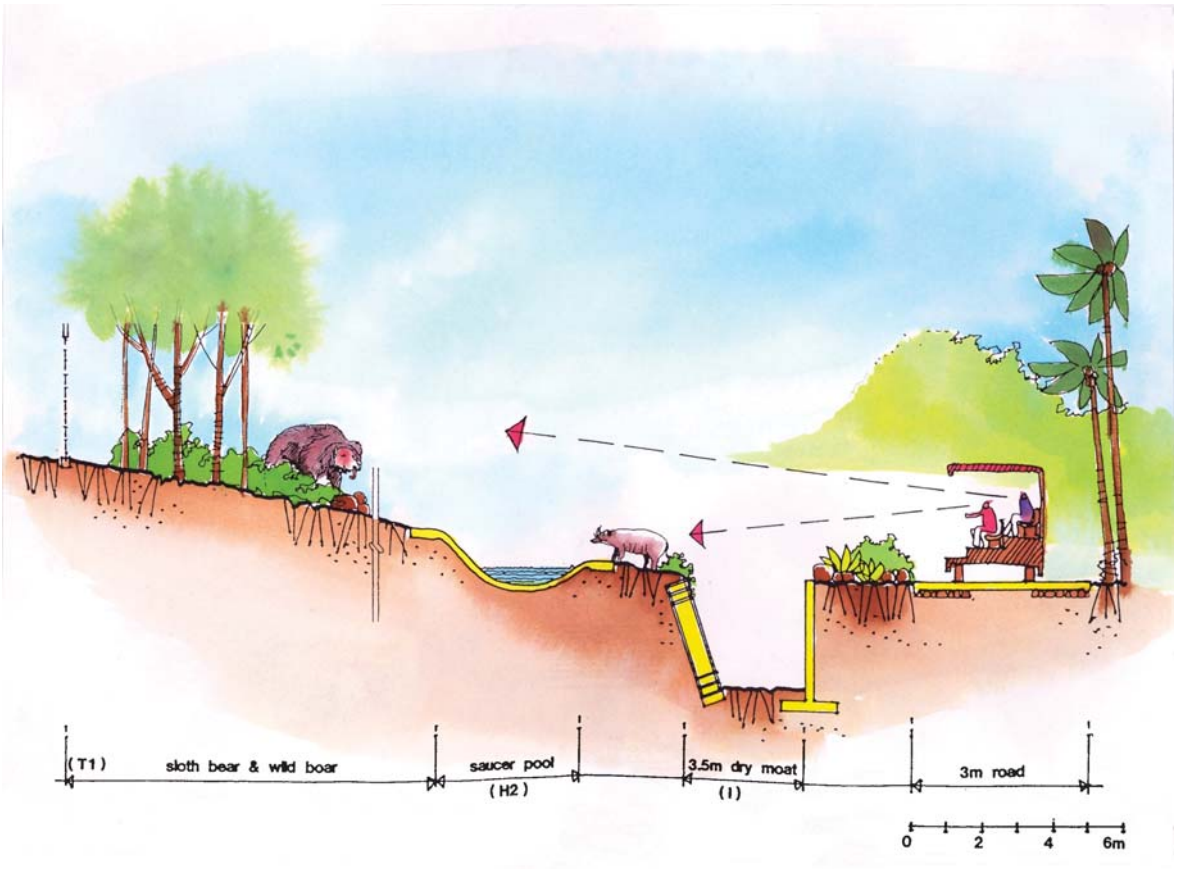


Illustration showing multi species exhibit with 'U' shaped moat for Sloth bear and power fence as a barrier for Wild boar.

3.3.3 Barrier Recommendations & Comments

The recommended front barrier design for sloth bears and Himalayan black bears is a U-shaped or V-shaped (flat bottomed) dry moat since these animals essentially inhabit drier environments, i.e. they are not closely associated with water / marshes. The Dehiwala Zoo at Colombo has however, constructed a wet moat as part of its sloth bear exhibit.

V-shaped moats look more natural than U-shaped moats and are less expensive to build and are therefore more desirable. If a U-shaped moat is built then the inner edge of the moat is sloped backwards to prevent the animal from falling into the moat.

Siltation of the moat bottom is bound to be created by animal movement on unstable moat edges; these should be protected from erosion with underground mesh lining. In very dry regions the sloped edge may have to be constructed out of exposed random rubble stone masonry in which holes can be left for natural scrub vegetation to grow. This is more natural looking than concrete or plastered brick and therefore desirable.

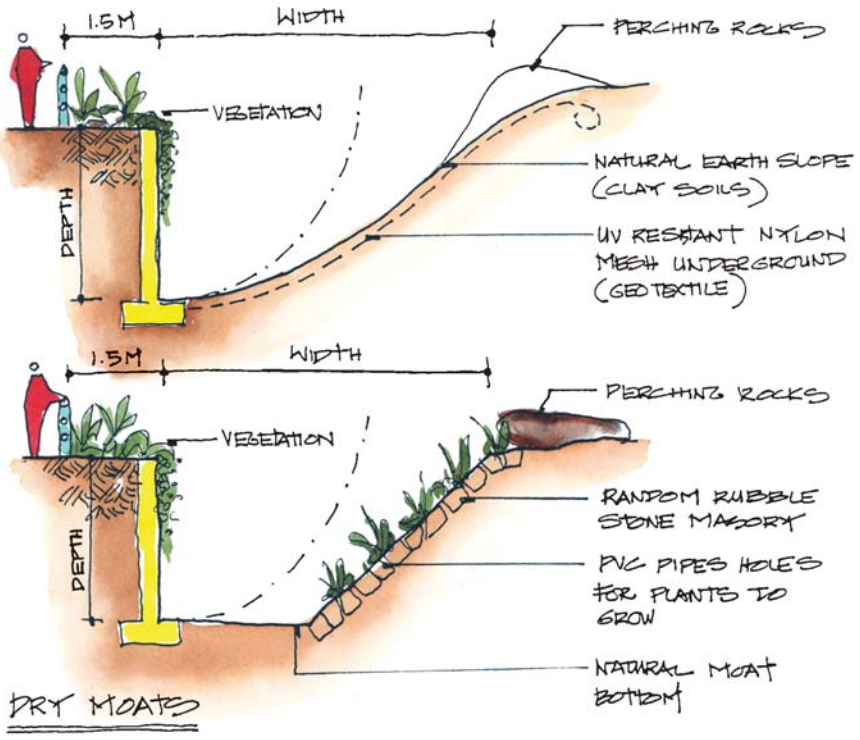
The recommended rear barrier design for sloth bears is also a U-shaped or V-shaped (flat bottomed) dry moat if space and a view is available behind the exhibit.

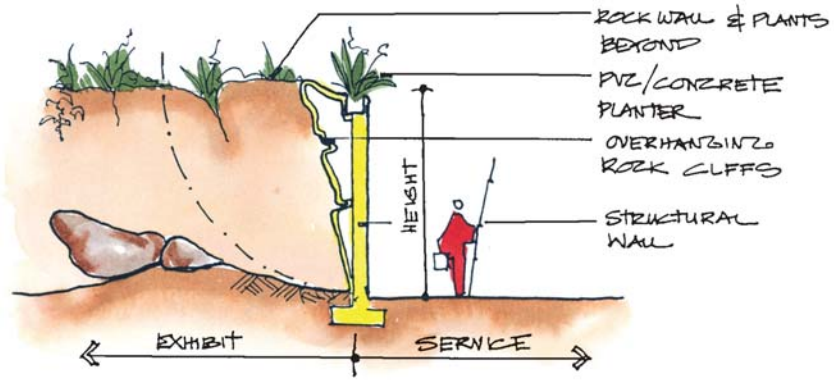
If space for a moat is unavailable then high walls may be used. The Hyderabad Zoo is of the opinion that the high wall provided as rear barrier should be made smooth to prevent the animal from escaping and fence should have overhangs.

Overhanging rock cliffs are aesthetically desirable as these bears often inhabit rocky slopes - but are very expensive to construct and should only be attempted if a realistic representation is possible. Normally this is beyond the skills of a civil work contractor and has to be executed by a rockwork artist or muralist. The Tirupati Zoo feels that any rock work provided as rear barrier should be visually merged as far as possible with the enclosure/habitat to camouflage it.

3.3.4 Schematic Barrier Diagrams

PHYSICAL BARRIER TYPES
Himalayan Black Bear, Sloth Bear





NOTE: THIS BARRIER TYPE CAN BE USED FOR LION & TIGER ALSO THOUGH THE EXTRA HEIGHT REQUIRED FOR THE BARRIER SINCE THOSE ANIMALS CAN JUMP MAKES IT VERY EXPENSIVE TO BUILD.

3.4 Arboreal species – jumping & climbing

3.4.1 Monkeys (Rhesus, Stump-tailed, Assamese, Crab-eating and Bonnet)

Nature of the Animal

Living mainly on trees in villages and in the foothills of jungles and the plains, troops of 20-30 monkeys may be found feeding on the ground or in the trees. Fruits, berries, leaves and shoots, insects and spiders form their diet. They are good swimmers. The Rhesus feeds mainly on the ground and eats ground plants, insects and spiders. Sometimes these macaques also raid cultivated fields and gardens. Adapted to urban life, these macaques can also be found in the busy streets of towns and around temples.

It is suggested that 4.5m wide and 4.5m deep V-shaped dry moat can be provided as front barrier, while a 5m high wall can form the rear barrier. Alternately a 5m high chain link fence with 1m wide inward inclined steel plate overhang can be provided.

Analysis of Barrier Dimensions

MONKEYS	Width (M)	Depth(M)/Height(H)	Moat type
Indian Zoos:			
Nehru Zoological Park, Hyderabad	N.A.	N.A.	Wet
Indira Gandhi Zoo, Vishakhapatnam	6.0	4.0	Dry
Arignar Anna Zoological Park, Vandalur	N.A.		Wet
S. V. Zoological Park, Tirupati	4.5	3.0	Dry
Foreign Zoos :			
Frankfurt Zoo	4.0	3.2	–
South Wales Zoo	4.5	4.5	–

N.A. - Not Available

Note: The fences should have smooth overhangs.

Barrier Suggestions

i) The following dimensions of moats have been adopted by different zoos. Vandallur and Hyderabad Zoo have provided wet moats while all other Indian Zoos have dry moats.

ii) Where space has been a constraints chain link covered enclosures have been provided.

iii) Chain link mesh open air enclosures of 5.5m height with 1m steel plate over hang can be provided. This will reduce cost of construction and structure shall be simple and can care large vegetated patches. However, care should be taken to see that the branches are not close to the fence. Bonet monkies, stump tailed monkies, Asamese macaques and Crab-eating monkeys can have enclosures of similar dimensions.

3.4.2 Lion-tailed Macaque

Nature of the animal

The Lion-tailed macaque inhabits the dense evergreen tropical forests of the Western Ghats. With a well developed whitish grey mane on its face and a tail with tuffs of hair at the end, like that of a lion, the Lion-tailed macaque has aptly earned its name. These monkeys are gregarious, living in troops of 10-20. They are diurnal in habit; they rarely come to the ground.

Analysis of Barrier Dimensions

LION-TAILED MACAQUE	Width (M)	Depth(M)/Height(H)	Moat type
Indian Zoos:			
Nehru Zoological Park, Hyderabad	8.4	2.45	Wet
Indira Gandhi Zoo, Vishakhapatnam	N.A.	N.A.	Wet
Arignar Anna Zoological Park, Vandalur	8.0	2.7	Wet
National Zooligical Park, Delhi	6.05	1.0	Wet
Kanpur Zoological Park, Kanpur	2.25	3.0	Wet

N.A. - Not Available

Note: The fences should have smooth overhangs.

Barrier Suggestions

i) It is suggested that 5.5 mt wide and 2.5 mt deep wet moats may be provided for them on the viewers' side, if sufficient water is available. The rear barrier can be of wall of 3.5m height or chain link mesh fence of 5m height with overhanging steel plate of 1.0m on the top. Moat dimensions adopted by different zoos are given in above table:

ii) If sufficient space and water for the moat is not available they can be housed an open air chain link fence with steel plate of the above indicated specification.

3.4.3 Langur (Common, Capped, Golden)

Nature of the Animal

Langurs live in forests, haunt shady groves around temples and make themselves quite at home in town and villages. They are pure vegetarian and feed on a variety of fruits, berries, buds and leaves. They spend much of their time on trees. Long–limbed and long tailed, they are extremely agile and make great leaps with extreme precision. Langurs live in groups comprising of 15-30 individuals of both sexes and all ages.

It is suggested to provide 5m wide and 4.6m deep dry moats on the visitors' side. The rear barrier can be a rubble wall of 5m height, if moat is not feasible.

The Capped langur can also be providing with enclosure of same moat dimension as suggested for common langurs.

The following dimensions of moats have been adopted by different zoos:

Analysis of Barrier Dimensions

LANGUR	Width (M)	Depth(M)/Height(H)	Moat type
Indian Zoos:			
Nehru Zoological Park, Hyderabad	N.A.	N.A.	Wet
Indira Gandhi Zoo, Vishakhapatnam	4.0	6.0	Dry
Arignar Anna Zoological Park, Vandalur	8.0	4.6	Wet
S. V. Zoological Park, Tirupati	8.0	2.6	Wet
Lucknow Zoological Park, Lucknow	10.0	5.0	Wet
Foreign Zoos :			
Night Safari, Singapore	6.0	N.A.	Wet
South Wales, Zoo	4.5	4.0	–

N.A. - Not Available

Note: The fences should have smooth overhangs

3.4.4 Nilgiri Langur

The Nilgiri Langur is found in the South Indian hill ranges in *sholas* or stretches of dense evergreen forest. They are not confined to forests and may invade gardens and belts of cultivated woodland. Their food is the customary vegetarian food of langurs but the species shows considerable adaptiveness. In planted areas the flowers and buds have become a major source of food. They are known to eat cardamom plant pith and other cultivated plants. They forage for food in the morning, rest at noontime and come out to feed again in the cool evening hours.

In the wild Nilgiri langur troops vary in size from 3 to 27 and averaging 8 to 9 animals per troop. Troop organization is on the basis of a single male leader with an adult sex ration of 1.2 female to 1 male.

Analysis of Barrier Dimensions

NILGIRI LANGUR	Width (M)	Depth (M)/Height (H)	Moat Type
Indian Zoos:			
Indira Gandhi Zoo, Vishakhapatnam	N.A.	N.A.	Dry
Arignar Anna Zoological Park, Vandalur	9	2.7	Wet
N.A. - Not Available			

Note: The fences should have smooth overhangs.

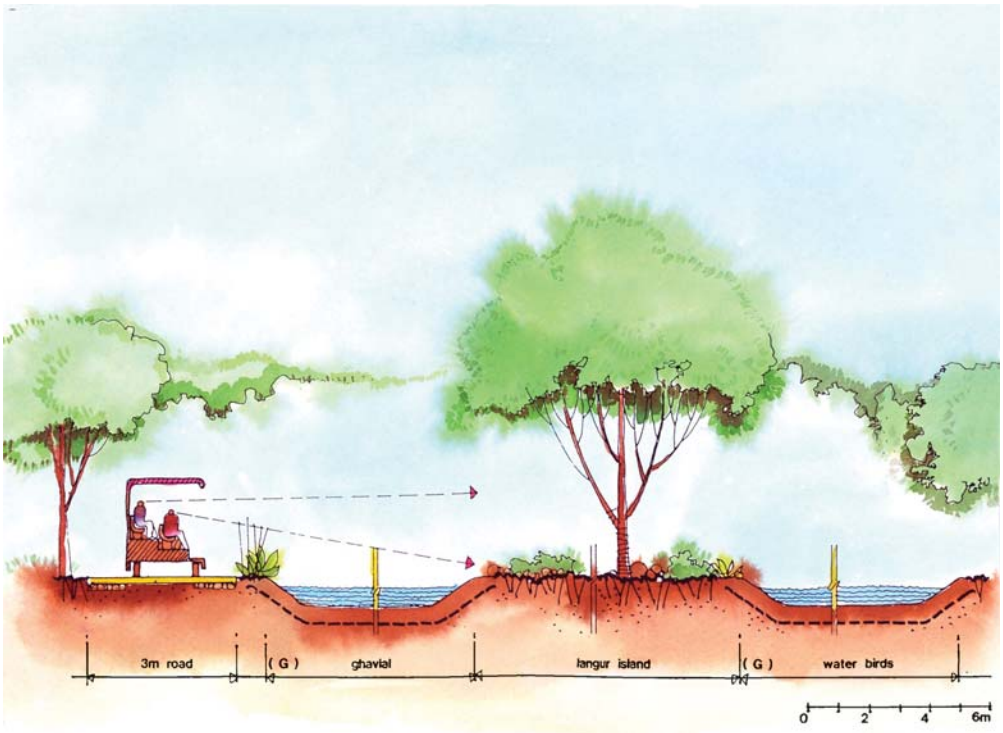
Barrier Suggestions

i) It is suggested that a 7m wide and 3.0m deep wet moat should be used on the visitors' side. If wet moat is difficult to maintain the dry moat depth should be 5m. The rear barrier can be of 5m tall sunken wall or chain link mesh fence of 5m height with 1m wide steel plate fixed on the top inclined inwards.

ii) Chain link mesh fence of the above dimension can be provided all around if space is a limitation. Large toughened glass windows can be provided at few places as viewing window. Of course maximum jumping distance should be maintained from tree branches.

3.4.5 Hoolock Gibbon

This is the only ape of the Indian subcontinent and inhabits the rain forest of North-East India. If is arboreal and often lives in tall tree branches and is omnivore. It is capable of precise long leaps.



Illustraion showing cross section of an Island type enclosure for arboreal Primates.

It is suggested to house them in islands encircled by wet moat as is afraid of getting in to water. The moat can be 8m wide and 2m deep.

3.4.6 Leopard/Jaguar

Though both leopard as well as Jaguar can be housed in open moated exhibit with using tools like solar fencing, this has been found to be risky due to their climbing and jumping ability besides timidity. They are often kept in covered chain link mesh enclosures of appropriate size. They can also be kept in open air enclosures with 5m high chain link mesh fence with 1m wide inclined steel plate fixed on top, leaning inwards. Care should be taken to see that no tree branch is within jumping distance from the fence.

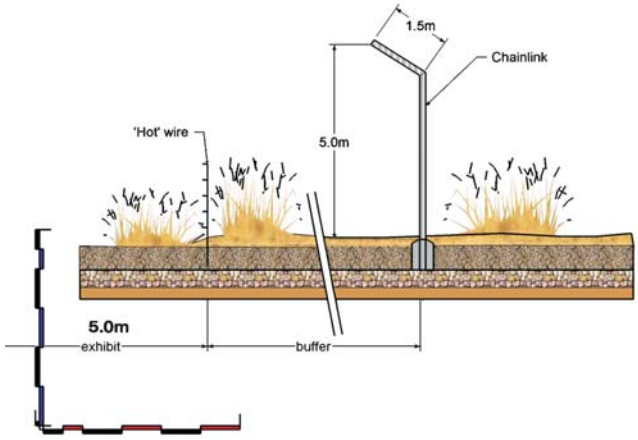


Illustration showing the cross section on the use of mesh fence with inclined inward steel plate overhang and providing additional barrier.

Toughened glass windows can be provided for unobstructed viewing

3.4.7 Barrier recommendations & comments

If enough space is available, different types of moats are the most realistic option for barriers for an open-air monkey exhibit as these animals are agile enough to climb most types of walls and fences. This essentially creates a monkey island type of situation, used successfully in zoos around the world.

The recommended front barrier and rear barrier design for macaques, and langurs is a shallow wet moat with 0.5 mt to 0.75 mts deep water as this can be designed to look like a naturalistic stream. Also, given the relatively small size of the animal, a shallow moat is less intimidating to the visitor than is a deep wet or deep dry moat.

A shallow wet moat has to be used in conjunction with an hot-wire fence in the middle of the moat to prevent the monkeys from wading across. The hot-wire fencing is a problem as it has to be insulated from the water surface.

Alternatively a deep wet moat with maximum of 0.5 mt to 0.7 mt depth of water can be used as a front barrier and rear barrier –but this option can only be used if the species in question is not a swimmer. The Monkey Park in Israel has used deep wet moats in conjunction with hot-wire fencing at the outer edge of the moats to deter even those monkeys known to be swimmers.

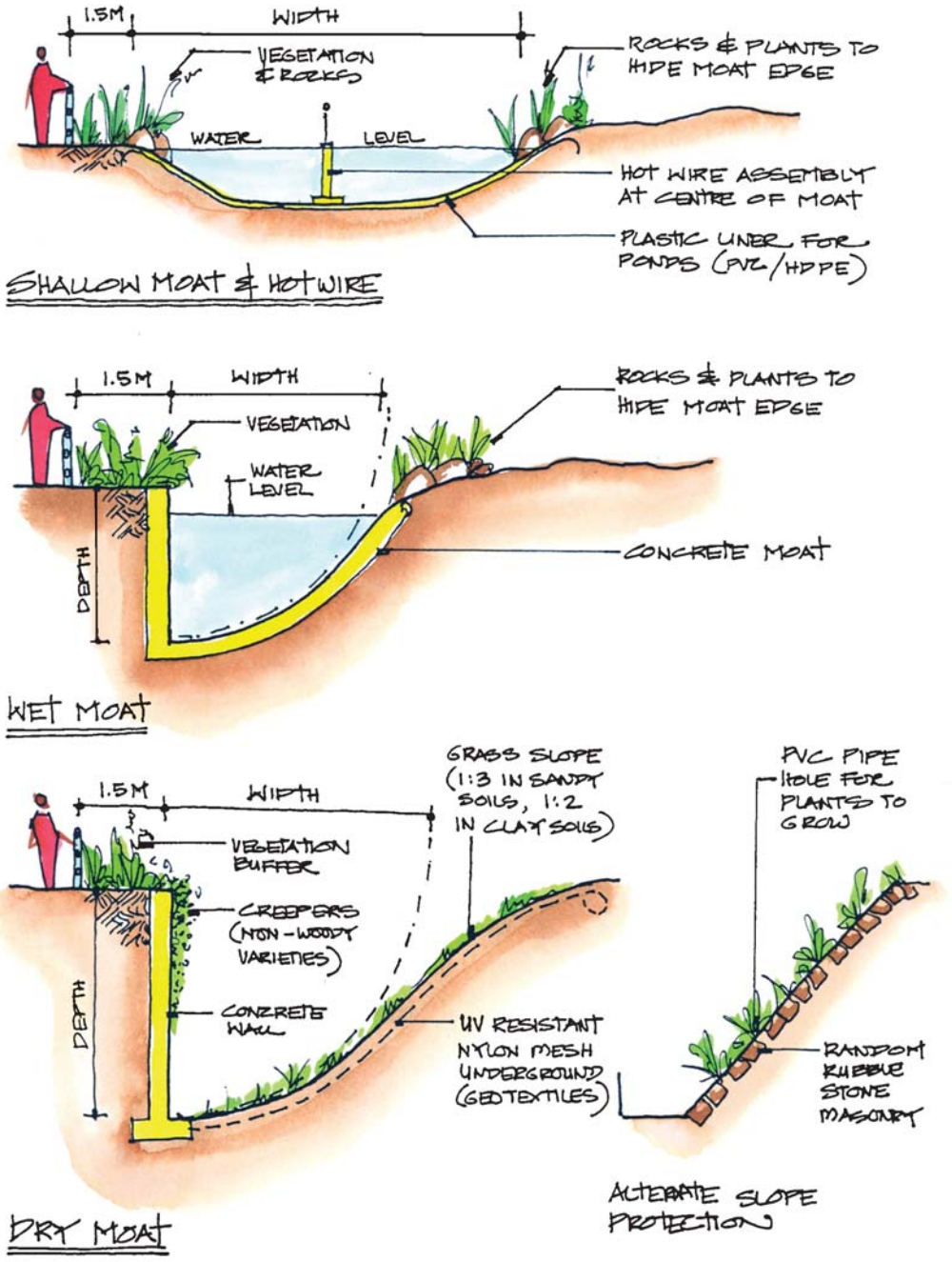
The third alternative is to use a deep dry moat larger than the minimum jumping distance as the front barrier and rear barrier. The Vishapkhapatnam Zoo is of the opinion that the minimum jumping distance should be maintained if a dry moated enclosure is provided for Nilgiri langurs.

The Hyderabad Zoo is of the opinion that monkey exhibits should be free of rodents, snakes, water snakes, as monkeys get scared by these creatures and opt to escape. High smooth walls are not recommended for monkey exhibits due to their expense and aesthetic unsuitability to a monkey exhibit except smooth walls resembling a traditional monkey temple may be considered if it fits the exhibit theme.

Snow leopard housed in chainlink mesh type enclosure at Padmaja Naidu Himalayan Zoological Park, Darjeeling

3.4.8 Schematic Barrier Diagrams

PHYSICAL BARRIER TYPES
Monkeys, Lion - tailed Macaque, Langur, Nilgiri Langur



3.5 Terrestrial species – non-jumping

3.5.1 Gaur

Nature of the animal

Gaurs are by nature are shy and timid animals. Their food is chiefly grass; they also browse on leaves and eat the bark of certain trees. Their defense is their massive size and an acute sense of smell. As with most wild cattle, hearing and eyesight are relatively poor. Gaurs are great wanderers and each herd has a large home range.

Gaur can be housed in a dry moated exhibit of 4m width and 1.5m depth with 2m high rubble wall on the back side.

The following are dimensions of moats used in different zoos:

Analysis of Barrier Dimensions

GAUR	Width (M)	Depth(M)/Height(H)	Moat Type
Indian Zoos:			
Nehru Zoological Park, Hyderabad	4.0	1.5	Dry
Indira Gandhi Zoo, Vishakhapatnam	10	1.5	Dry
Arignar Anna Zoological Park, Vandalur	4.0	1.8	Dry
S. V. Zoological Park, Tirupati	7.0	2.0	Dry
Foreign Zoos :			
Night Safari, Singapore	3.5	N.A.	Dry

N.A. - Not Available

Note: The Detroit Zoo in U.S.A. has been using 2.4m W x 5.2m H barrier.

3.5.2 Wild Boar

Nature of the Animal

The Indian Wild Boar lives in grassy or bushy forests, and even in dense forest. They are omnivorous, living on crops, roots, tubers, insects, snakes, offal and carrion. The Wild boar is highly prolific breeder and breed in all seasons. It's elongated canine teeth allows it to dig out earth for tubers.

Wild boars can be hosed in moated enclosure with 4m wide and 15m ry moat in front. The rear barriers can be of low wall or of chin link mesh . In case of using chain link mesh, it should be ensured that the mesh is thick and properly embedded in to the concrete base as they are capable of digging and escaping.

Analysis of Barrier Dimensions

GAUR	Width (M)	Depth(M) /Height(H)	Moat type
Indian Zoos:			
Nehru Zoological Park, Hyderabad	4.0	1.5	Dry
Indira Gandhi Zoo, Vishakhapatnam	1.0	1.5	Dry
Arignar Anna Zoological Park, Vandalur	4.0	1.8	Dry
S. V. Zoological Park, Tirupati	7.0	2.0	Dry
Foreign Zoos:			
Night Safari, Singapore	3.5	N. A.	Dry

N. A. - not available

3.5.3 Rhinoceros

Nature of the Animal

The Great Indian One horned rhinoceros is not only the largest but also the most pre-historic in appearance. Rhinos are found in the swamps of North East India, with a fair concentration in the Kaziranga National Park in Assam, North Bengal and in the flood plains of the rivers of Nepal.

Though it prefers swamp and grass land, the great Indian one horned rhinoceros is also found in wooded forests up in ravines and low hills. They are not social animals and groups exceeding tree is a rare sight. The animal is solitary as a rule, through several may occupy the same patch of forest / grass land.

Rhinos can be confined in enclosures with dry moat of 3.5m width and 2.5m depth on the viewers side. On the back side 2.0m rubble wall is ideal. Different zoos have used different dimensions of moats dry or wet as given below:

Analysis of Barrier Dimensions

RHINOCEROS	Width (M)	Depth (M)/Height (H)	Moat Type
Indian Zoos:			
Nehru Zoological Park, Hyderabad	7.46	3.76	Wet
Arignar Anna Zoological Park, Vandalur	7.0	6.0	Dry
Assam State Zoo, Guwahati	4.5	2.0	Wet
National Zoological Park, Delhi	6.85	2.38	Wet
Lucknow Zoological Park, Lucknow	N.A.	2.0	Dry*
Kanpur Zoological Park, Kanpur	2.5	2.5	Dry
Foreign Zoos :			
London Zoo, London	3.35	2.22	–
Whipsnade Wild Animal Park, Whipsnade	N.A.	2.05	–
Night Safari, Singapore			

*Overhang of 1.75 M is part of the barrier.
N.A. - Not Available

Rhinoceros enclosure at Assam State Zoo, Guwahati which also houses Spotted and Barking deer.

3.5.4 Asian elephant

Nature of the animal

The Asian elephant is a predominantly gregarious forest animal whose social organization is based on a family unit commanded by old female. A herd may consist of between 5 to 20 or more individuals. Elephants are entirely herbivores in their dietary habit; feed on a variety of grasses, leaves, fruits and bark. Herd is believed to be composed of single families. Elephants sleep during the hot hours of the day, being intolerant of the sun, feed early in the morning and evening, and come out after nightfall to feed in open forest. The trunk is capable of grasping objects in different directions like our hands.

Barrier Suggestions

i) The suggested top width of dry moat is 3.5m and depth of 2.5m. A low rubble wall on sides other than viewers' side can be provided.

ii) Other barrier options are B.G. rail barrier of 1.2m height quite away from viewers, so that the trunk can not reach.

iii) Rubble walls of 1.5m height of 0.75m wide can also keep the elephants confined.

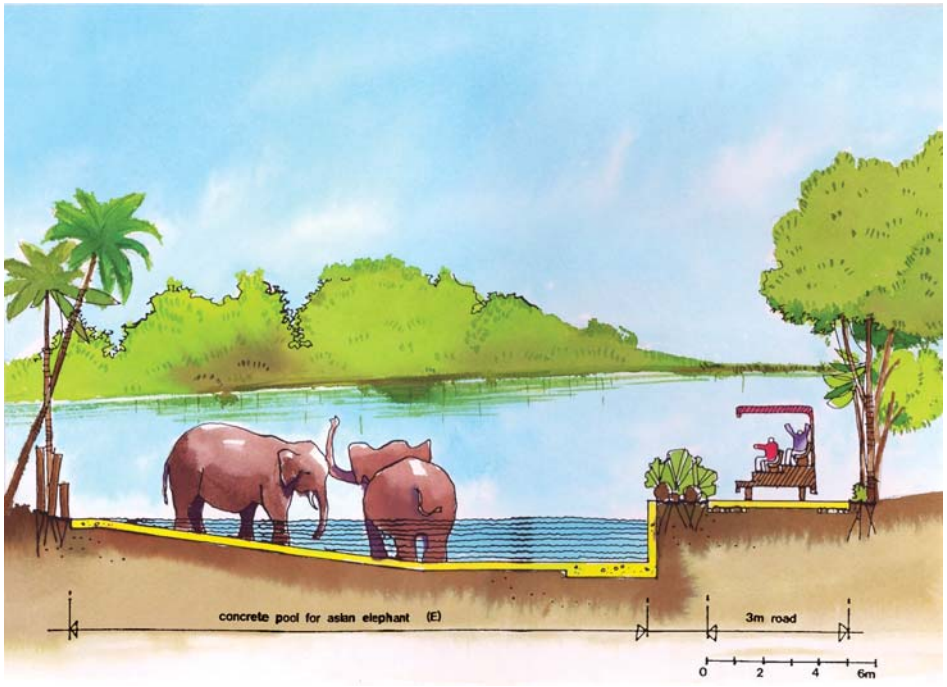


Illustration showing cross section of an Elephant enclosure with wet moat.

The following dimensions of moats have been adopted in different zoos:

Analysis of Barrier Dimensions

ASIAN ELEPHANT	Width (M)	Depth(M)/Height(H)	Moat type
Indian Zoos:			
Nehru Zoological Park, Hyderabad	2.38	1.97	Dry
Indira Gandhi Zoo, Vishakhapatnam	3.0	1.7	Dry
Arignar Anna Zoological Park, Vandalur	4.65	2.0	Dry
National Zoological Park, Delhi	2.74	2.14	Dry
Lucknow Zoological Park, Lucknow	3.0	3.5	Dry box moat
Foreign Zoos :			
Whipsnade Wild Animal Park, UK	3.5	1.25	–
Frankfurt Zoo, Germany	4.5	1.1	Dry

3.5.5 Barrier recommendations & comments

The recommended front barrier design for Gaur, Wild Boar, Rhinoceros, and Asian Elephant is a V-shaped (flat bottomed) dry moat to prevent the animals from falling in and hurting themselves. V-shaped moats are also more natural looking than U-shaped moats and cheaper to build and are therefore are desirable. The disadvantage of a V-shaped moat is that the animal can enter the moat making it less visible to visitors. This can be dealt with by providing enough enrichment within the habitat itself and by keeping the moat bottom free of grasses. The moat should have steps/ ramp for emergency with suitable door at far end of the moat as elephant, gaur, and rhinos in particular are not agile enough to walk back up the sloped sides, if they get inside the moat.

Since these are all heavy grazing animals that tend to destroy a natural moat edge, the sloped moat edge should be constructed out of exposed random rubble stone masonry in which holes can be left for natural scrub vegetation to grow. This is more natural looking than concrete or plastered brick and therefore desirable.

The recommended rear barrier design for the Gaur, Wild Boar, Rhinoceros, and Asian Elephant is a V-shaped (flat bottomed) dry moat if space and a view is available behind the exhibit.

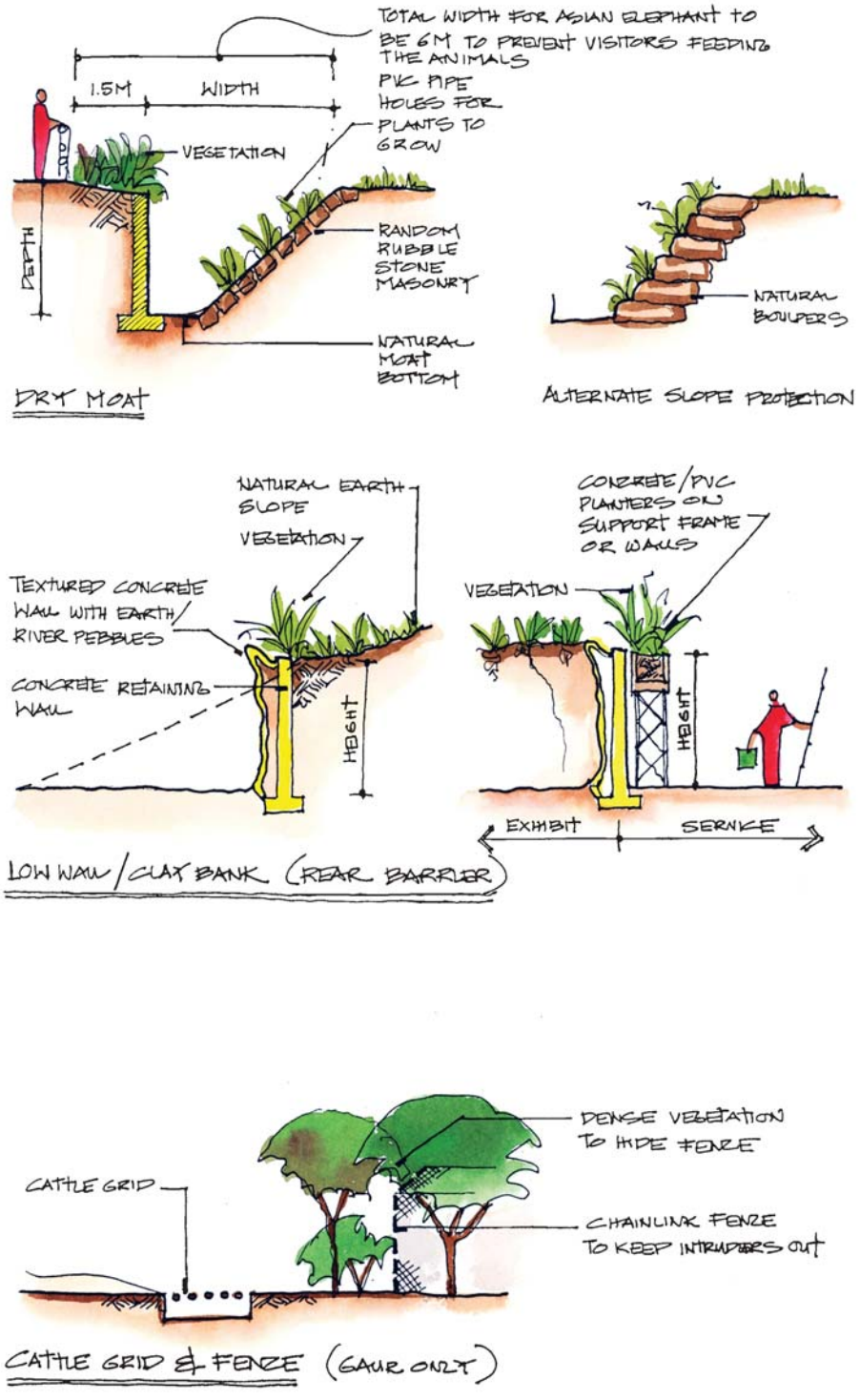
If space is not available behind the exhibit then the recommended rear barrier design is a low wall that can be disguised as a clay river bank. If the ground behind the wall is higher than the exhibit then this clay-bank acts as a retaining wall. Vegetation can be grown on the earth just behind it.

A rail barrier or thick pipe can keep the elephants confined.

An alternative rear barrier for gaur is a wide cattle grid beyond which a chain-link fence hidden in vegetation can be used to keep intruders out of the exhibit. This construction can turn out to be cheaper than either moats or walls while being just as effective.

3.5.6 Schematic Barrier Diagrams

PHYSICAL BARRIER TYPES
Gaur, Wild Boar, Rhinoceros, Asian Elephant



3.6 Aquatic & semi-aquatic species – non-jumping

3.6.1 Hippopotamus

Nature of the animal

The Hippopotamus is found in Liberia and Ivory Coast, a few also in Sierra and parts of Southern Nigeria. It live in rainforests and swamps. It feeds on roots, grasses, shoots and fruits and found in forest floors. Its mouth is alarmed with large canine tusks. When alarmed the Hippopotamus prefers to take refuge in dense forest rather than in water.

Analysis of Barrier Dimensions

HIPPOPOTAMUS	Width (M)	Depth(M)Height(H)	Moat type
Indian Zoos:			
Nehru Zoological Park, Hyderabad	3.0	1.75	Wet
Indira Gandhi Zoo, Vishakhapatnam	6.0	1.8	Wet
Arignar Anna Zoological Park, Vandalur	11.3	3.3	Wet
Assam State Zoo, Guwahati	N. A.	2.2	Wet
Lucknow Zoological Park, Lucknow	N. A.	2.25	Wet
Kanpur Zoological Park, Kanpur	N. A.	2.0	Wet

N. A.. - not available

Naturalistic enclosure for Hippopotamus at Nandankanan Zoological Park at Bhubaneshwar.

3.6.2 Crocodile (Gharial, Mugger and Estuarine Crocodile)

Nature of the animal

Among the Crocodilians of the world, gharials are the largest. A male Gharial grows to more than 7 m, and a female to 5 m. Compared with other species of crocodilians, the gharial is more aquatic in its habit. They live in natural river gorges where water is deep and currents are slow.

The following dimension of barrier used by different zoos is provided below:

Analysis of Barrier Dimensions

CROCODILE	Width (M)	Depth(M)/Height(H)	Moat type
Indian Zoos:			
Nehru Zoological Park, Hyderabad	3.0	1.5	Wet
Indira Gandhi Zoo, Vishakhapatnam	N. A.	1.7	Wet
Arignar Anna Zoological Park, Vandalur	N. A.	N. A.	Wet
National Zoological Park, Delhi	1.58	1.58	Wet
Kanpur Zoological Park, Kanpur	N. A.	2.0	Wet
Foreign Zoos :			
Singapore Zoological Garden, Singapore	3.0	N. A.	Wet

N.A. - Not Available

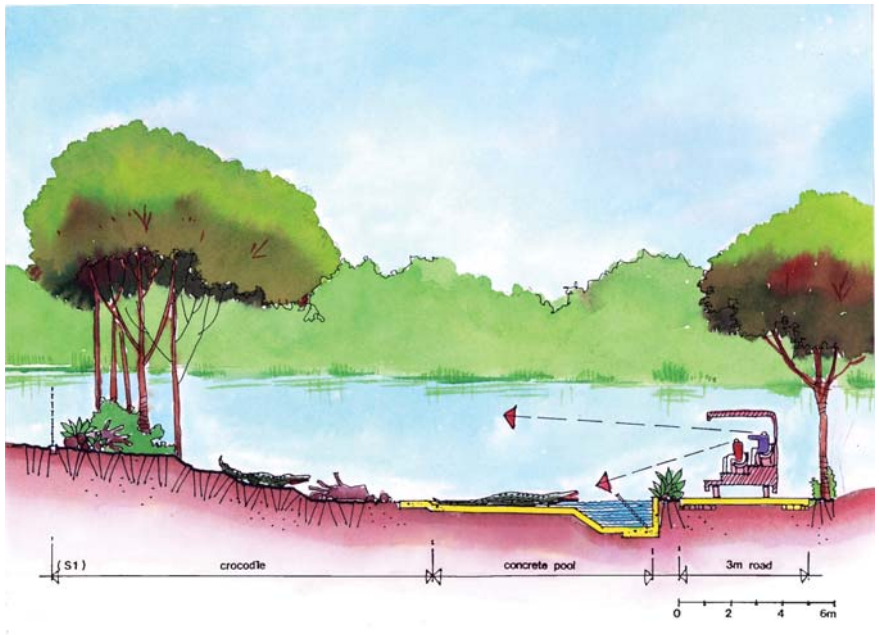


Illustration showing cross section of a Crocodile enclosure.

Barrier Suggestions

i) It can be housed in moated enclosures or partly moated enclosures both wet & dry of 3m width & 1.5m depth. The back side can have rubble walls of 2m height. When dry moat is provided the water body should be away from the same.

ii) Other 2 species of Indian crocodilians i.e. mugger and estuarine crocodile can have similar moats with 2m deep moates with rubble walls on the back side.

iii) Where under water viewing is arranged with toughened water proof glasses below water level, the minimum moat size should be at least 5m wide 1.5m deep with raised wall above the glass viewing window.

iv) The sand should be made available in appropriate amount inside the Gharial enclosure for basking.

3.6.3 Otter

Nature of the animal

Otters live in groups but they usually search for food on their own, in water or in hand. They feed on fish, frogs, land birds and small mammals. Most of them hunt during the day. Otters come ashore to give birth to their young ones. The newborn are blind and are carefully guarded by their mother. Sleek, streamlined and energetic, the otter rarely remains still. An Otter's flexible body and webbed feet makes it an underwater acrobat.

Analysis of Barrier Dimensions

COMMON OTTER	Width (M)	Depth(M)/ Height(H)	Moat type
Indian Zoos:			
Nehru Zoological Park, Hyderabad	4.0	2.5	Wet*
Assam State Zoo, Guwahati	N. A.	1.4	Wet
National Zoological Park, Delhi	1.58	1.58	Wet
Kanpur Zoological Park, Kanpur	2.5	2.0	dry moat with pond
Foreign Zoos:			
London Zoo		1.7	

* includes under water viewing
N. A. - not available
Note : Taronga Zoo, Australia, has 1.5m high inclind fence with fine mesh and smooth river bank 1m above water level.

3.6.4 Barrier Recommendations & Comments

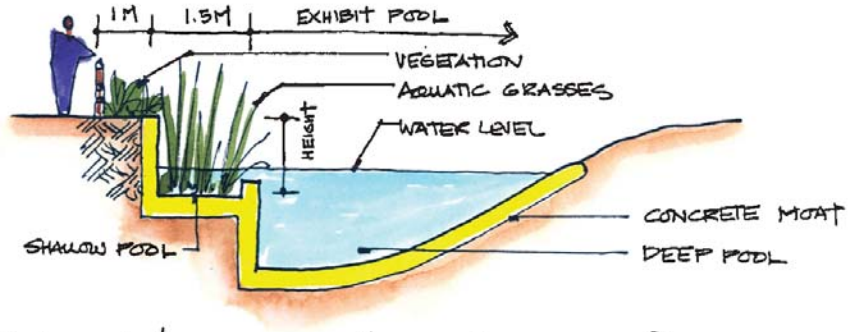
The recommended front barrier design for the Hippopotamus, Crocodile, and Otter is a U-shaped or V-shaped wet moat that also serves as the exhibit pool. Since these animals are aquatic in nature their habits can thus can be observed up close by visitors.

By manipulating ground levels underwater viewing can also be created for these animals as has been done for the Common Otter at the Hyderabad Zoo.

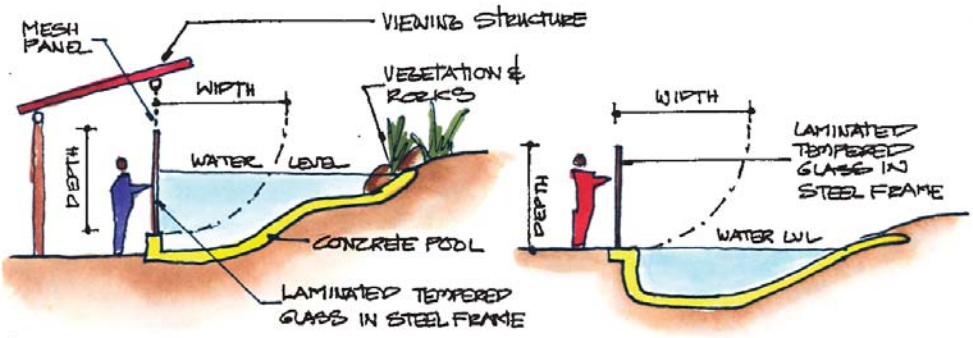
The recommended rear barrier design for Hippopotamus, Crocodile, and Otter is a low wall that can be disguised as a clay river bank. If the ground behind the wall is higher than the exhibit then this clay-bank acts as a retaining wall and has vegetation grown in the earth just behind it.

3.6.5 Schematic Barrier Diagrams

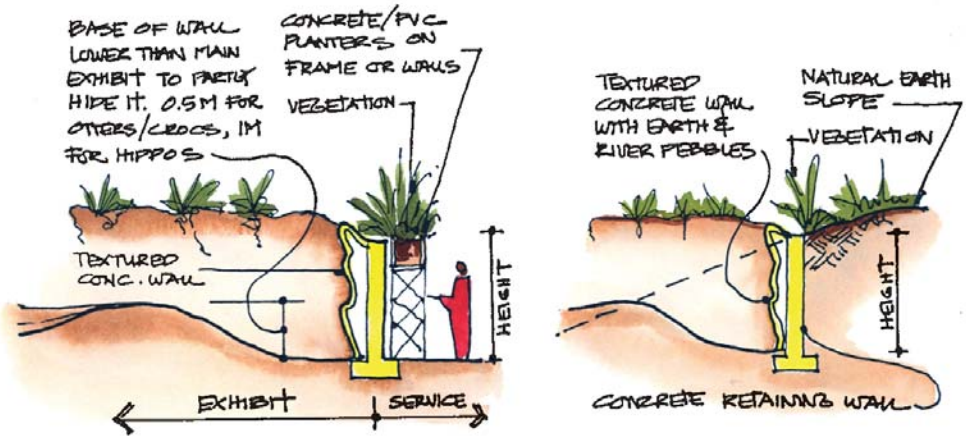
PHYSICAL BARRIER TYPES
Hippopotamus, Crocodile, Otter



WET MOAT/EXHIBIT POOL (HIPPO & CROCODILE)



GLASS (SURFACE & UNDERWATER) VIEWING (OTTER & CROCODILE)



LOW WALL/CLAY BANK (REAR BARRIER)

3.7 Crawling animals

3.7.1 Snakes and lizards

These animals can be exhibited in glass fronted exhibits. The size of enclosures may vary from species to species depending on the size. The glass should be installed in such a way that visitor's image reflection should be avoided. The exhibit may be closed on top by providing fine mesh. This shall allow natural light and rain water inside the enclosure.

Reptile exhibit using glass as a barrier at Nehru Zoological Park, Hyderabad.

3.8. Birds

3.8.1. Flightless birds

Flightless birds like Ostrich, Emus, Rhea and Cassowary etc can be safely housed in open moated enclosure like those provided for terrestrial non-jumping animals. The moats can be of 2m wide and 1.5m deep in the front, while the rar sides can be protected with rubble wall/ chain link fence 1.5-2m. high.

Aviary for pheasants at Himalyan Zoological Park, Gangtok

3.8.2. Flying birds

These birds can be housed in chain link covered enclosures of dimension depend on size and flying habit of the bird or birds to be kept. Glass windows are options for unobstructed viewing. Piano wire barrier can be tried for much better effect. The structural stability of the aviary should be ensured before its inception.

Aviary for pelicans at Nandankanan Zoological Park, Bhubaneshwar

4.0. Off-display exhibits

Animals housed for conservation breeding programmes, rescued animals, injured/sick animals or those being quarantined need not be displayed to visitors. Hence moated or otherwise expensive enclosures are not required. Such enclosures should be designed safe, meeting the animal's biological and functional need and should be user friendly. Hence they can be of chain link mesh of appropriate dimension covered or open air depending on the species to be housed. Use of other type of barriers should also be explosed. The use of steel should be minimized.

Enclosure for tigers at Rescue centre, Indira Gandhi Zoological Park, Vishakhapatnam

Off display aviary for vultures at Vulture Breeding Centre, Pinjore

Vultures provided with adequate screening and wooden logs as environmental enrichment

Pigmy Hog enclosure at Pigmy Hog Conservation Breeding Centre in Vashistha, Guwahati

5.0 Guidelines of the Central Zoo Authority on use of Innovative Exhibit Design and Barriers for holding and display of Animals in Indian Zoos*

1. Animal Types, Enclosure & Barrier Recommendations

Animal	Front barrier	Rear barrier	Remarks
Tiger, Asiatic Lion	V-shaped dry or wet moats, glass viewing structures at special viewing areas. Depth of moat: 5mts Horizontal width at the top: 8 mts	U-shaped dry moats OR chain-link fences of 5 mt high with 1.5 mt overhang at 60° angle OR high rock walls.	a. The hot wire barrier may be provided to prevent animals coming into the moat b. In case of want of space for a moat, all sides can be provided with chain link mesh fence with glass fixed at 2/3 places for unhindered viewing.
Leopard/Jaguar	1. Chain link mesh fence of 4 mt. high with inclined inward steel plate of one meter width on the top. The steel plate should be placed at the angle of 60°. 2. Wherever space is available 5 meter deep moat with overhang of hot wire.		For a unhindered vision, use of toughened glass of proper specifications at one or two points could be used.
Jackal, Wolf, Hyena	V-shaped (flat bottomed) dry moats on the visitor side. Depth of moat: 2.6 mts Width of moat: 5 mts	V-shaped (flat bottomed) dry moats OR chain-link fences of 2.5 mts in height.	
Bear/Civets/Lesser cats	U-shaped / V-shaped dry moats on the visitor side.	U-shaped / V-shaped dry moats OR high smooth walls, OR chain link fence of 4 mt. high with inclined inward steel plate of one meter width on the top.	The steel plate should be placed at the angle of 60°.
Primates	U-shaped / V-shaped dry moats, shallow wet moats, netted aviaries with glass viewing. Moat width for langur: 7 mts Moat depth for langur: 5 mts		a. In case of moated enclosures, the inner side of the enclosure should be provided with overhang with 2 stands of hot wire attached below the

* Approved during the meeting of experts held in the Office of Central Zoo Authority, New Delhi on 28th November, 2006.

	Moat width for macaque: 6 mts Moat depth for langur: 4 mts Or chain link mesh of 5 mt high with inclined steel plate of 1 mt width.		slanting portion. b. The moated enclosure should have clearance of tree of at least 9 mts from the inner side of fence/ moat.
Deer and antelopes	Chain-link fences all around the paddock, V-shaped (flat bottomed) dry moats of 2.5 mt depth having slope width of 6 mts.	V-shaped (flat bottomed) dry moats OR chain-link fence.	a. The visitors view should be restricted. b. Slope should be grass sodded (turfed) or stone pitched depending on the site condition.
Gaur, Wild boar, Rhinoceros, Asian elephant	V-shaped dry moats, Or low walls (clay banks), cattle grids (for gaur) or 5 meters away a sunken B.G. Rail Barrier with 1 to 1.5 mt high or hot wire fence made in depression, created by excavating earth for camouflaging it from viewer.		
Pheasants	Covered type enclosure of wire mesh of 3 meter high, 8 mt. depth, 4 mt width		a. The double galvanized mesh of 12mm x 12mm x 4g should be placed 0.5 mt below the earthen surface to prevent rodents. b. The plinth should have 7 cm (over hang) to prevent rodents/snakes approaching the chain link mesh from the viewer side or either side.
Walk through aviary	i. The area for the walk through aviary should not be less than 2 hectares with at least 100 mts wide withdrawal area for the birds. ii. The height of the aviary should be 18 mt.		a. Adequate vegetation should be providedb. b. Provision of board walk shall be ideal for visitors.
Terrestrial birds	The height of the mesh covered enclosure should be at least 5 meters.		Sufficient vegetation and perches should be made available to the birds.
Water bird aviary	i. The chain link mesh covered aviary could be ideal. ii. The height of the aviary should be kept 12 mt.		a. The chain link used for the aviary should be off 45 m x 12-15 m in dimension.

		b. The 50% of the enclosure area should be covered by water body with flaring angle or aeration.
Birds of Prey/ flying birds Crocodile / Gharial enclosure	The dimension of the chain link mesh covered should be 45 mt x 12-15 mt x 12 mt high Open 'V' shape moated enclosure with dry moat should be provided.	a. It must be ensured that enclosure should have at least 20% space covered by water (pool). b. Sufficient area shall be provided for basking. Sand must be available for gharials.

2 (a). Other decisions on the use of barrier for displaying of animals:-

(i) It was agreed there should be increasing use of other barriers like hot wire (power fence), concealed ones, glass fronted viewing, rails etc.

(ii) Use of stainless steel instead of mild steel, particularly on posts and chainlink mesh should be encouraged due to its longevity, avoidance of rust and lighter weight.

(iii) Environmental enrichment like perches, dens, ledges, nesting boxes, feeding logs, wooden logs, wooden platform, wallow, pools, logs, vegetation, bunchy earth should be provided in the exhibits. For this a letter can be addressed to all the zoos for sending their plan with requirement of funds for the purpose. This can be supported by CZA as it is a small component.

In case of new enclosures, it should be in built with the design and should be limited to 2% of cost.

(iv) Nocturnal animal houses should be provided with adequate space, with open air kraal and sufficient number of animals to be rotated and arrangement for proper regulation of lighting.

(v) Reptile houses particularly in the cooler regions, should be covered and glass fronted with assured heating arrangement in winter i.e. back up power supply.

(vi) Large, medium and small zoos located in urban areas or within 500 meters from human habitations should be bounded with perimeter wall on all sides of 2 mt. height from the ground level.

(vii) In case of zoos with less than 10 hectares area, creation of moated enclosures should be avoided.

2(b) Use of different materials in barriers

Use of different material in designing barriers at animal enclosures was discussed and it was decided to use many alternative materials like stainless steel mesh and posts, anodized aluminum frame, piano wire, hot wire (power fence), glass, vegetation, rail, invisible cattle grid type barrier.

2(c) Use of alternatives

No particular barrier can be specified for all situations. Different materials can be used either completely or in combination depending on the species, space, availability, topography, climate and existing display type of the zoo. There should be scope for innovation by the zoo management.

6.0 Compilation of Illustrations and Images on various types of Barrier Designs used in Zoos.

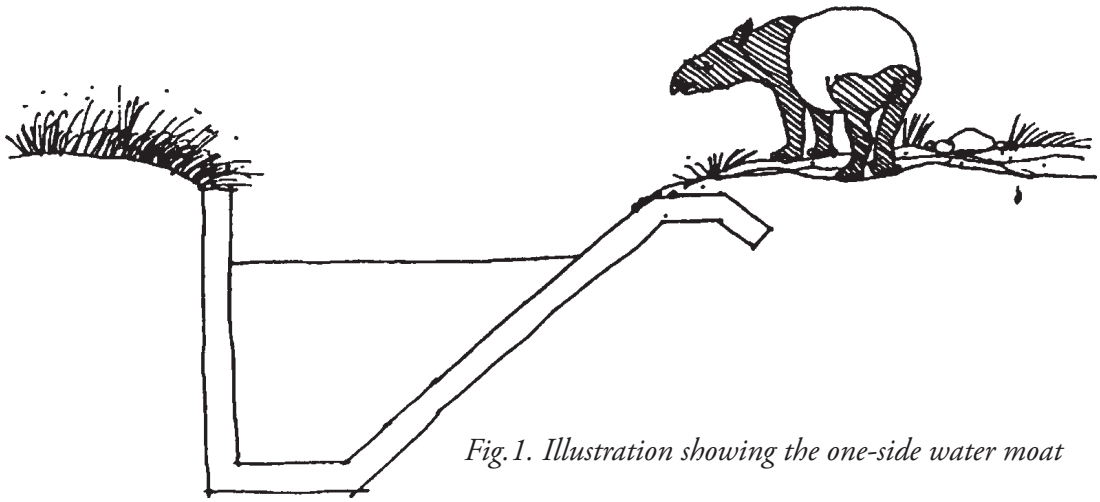


Fig.1. Illustration showing the one-side water moat

Fig.2. Chimpanzee enclosure at National Zoological Park, New Delhi using water moat as a barrier.

Fig.3. Hyena enclosure using dry moat as a barrier at Sri Venkateswara Zoological Park, Tirupati.

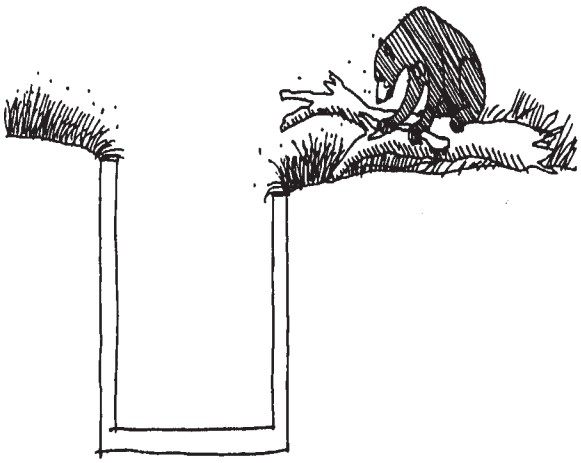


Fig.4. Illustration showing box type hidden dry moat.

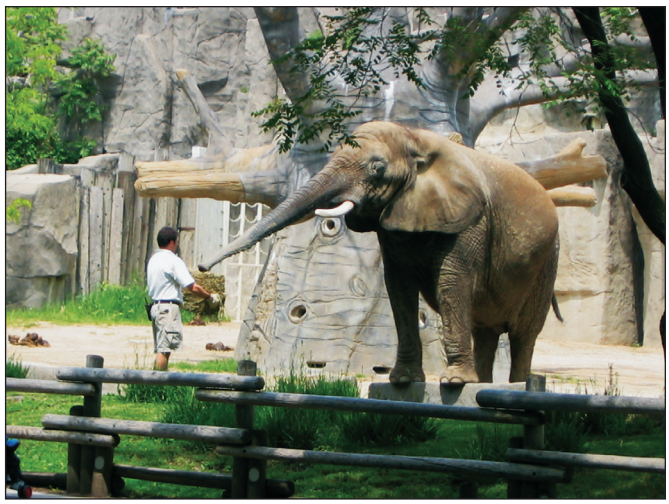
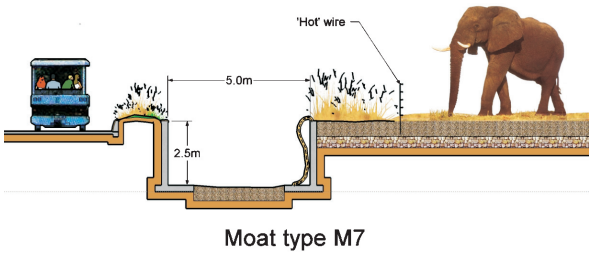


Fig.5. Elephant enclosure using hidden dry moat at Brookfield Zoo, Chicago.



Moat type M7

Fig.6. Elephant enclosure illustration with box type dry moat.

Fig.7. Elephant enclosure at Night Safari, Singapore.

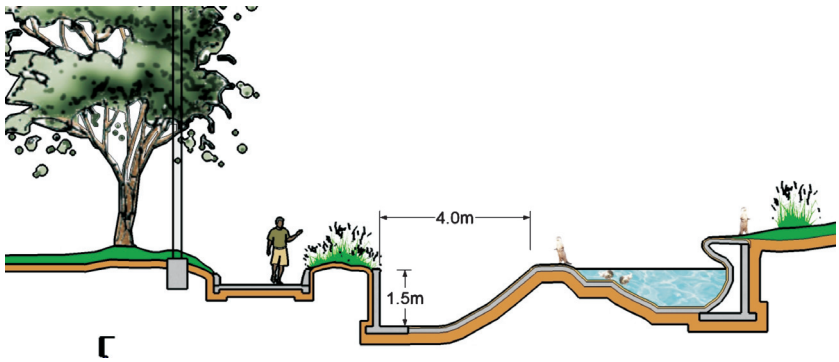


Fig.8. Illustration showing moat type enclosure with a water pool for Otters.

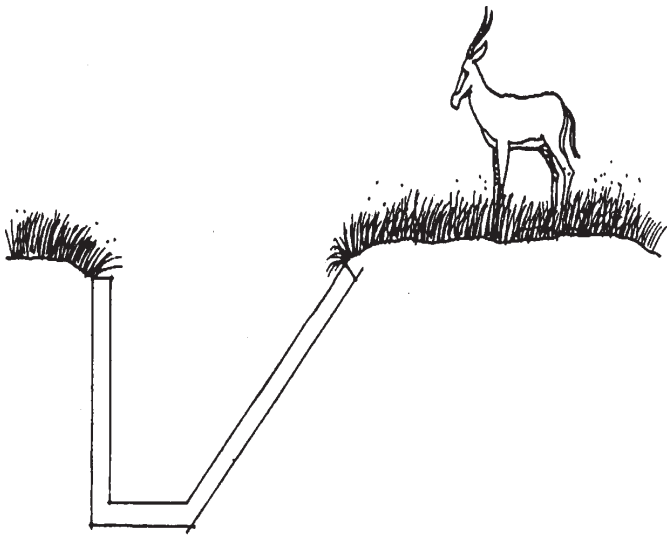


Fig.9. Illustration showing one-sided dry moat

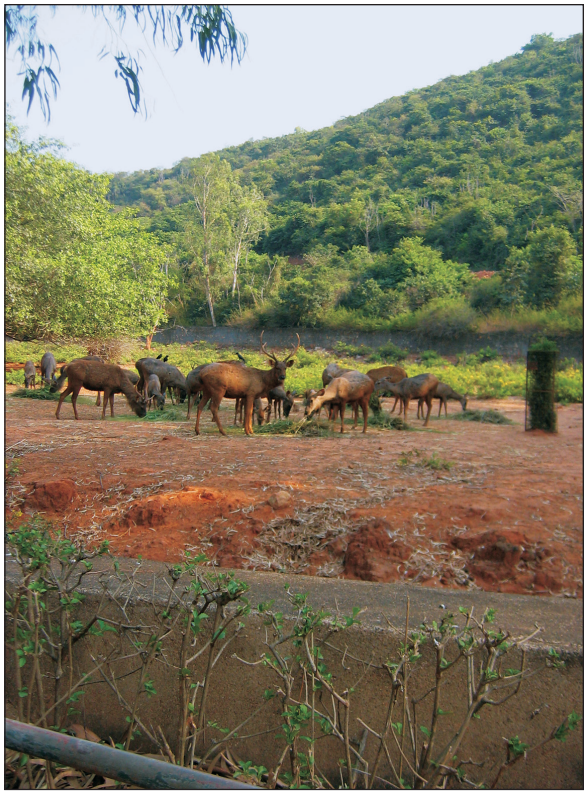


Fig.10. Sambar enclosure at Indira Gandhi Zoological Park, Vishakhapatnam using dry moat as a barrier.

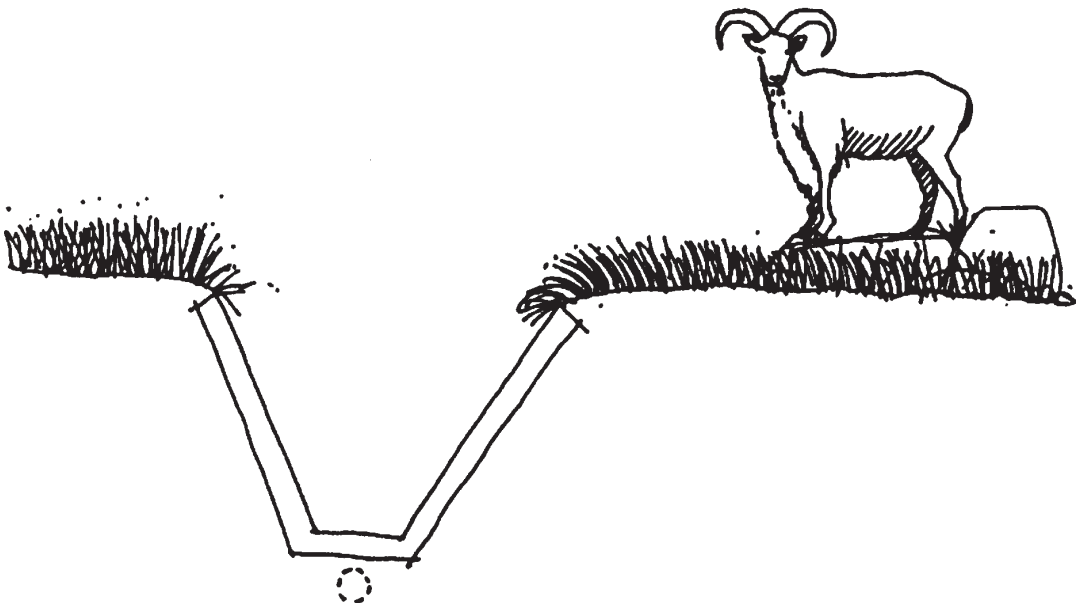


Fig.11. Illustration showing 'V' shaped moat.

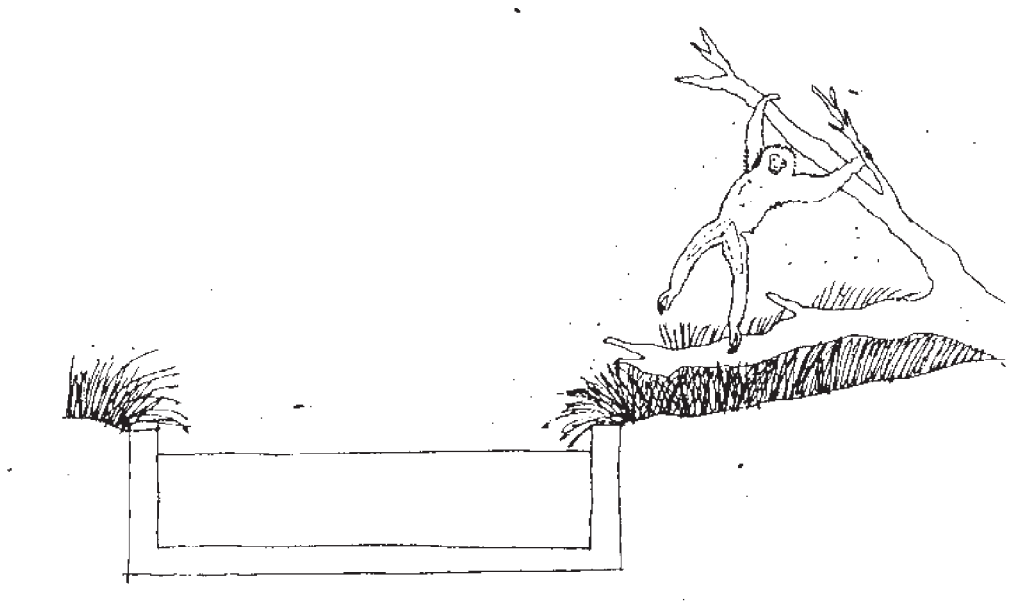


Fig.12. Illustration showing shallow dry moat for arboreal primates.

Fig.13. Wet moat enclosure for Hoolock gibbon at Aizawl Zoo, Mizoram.

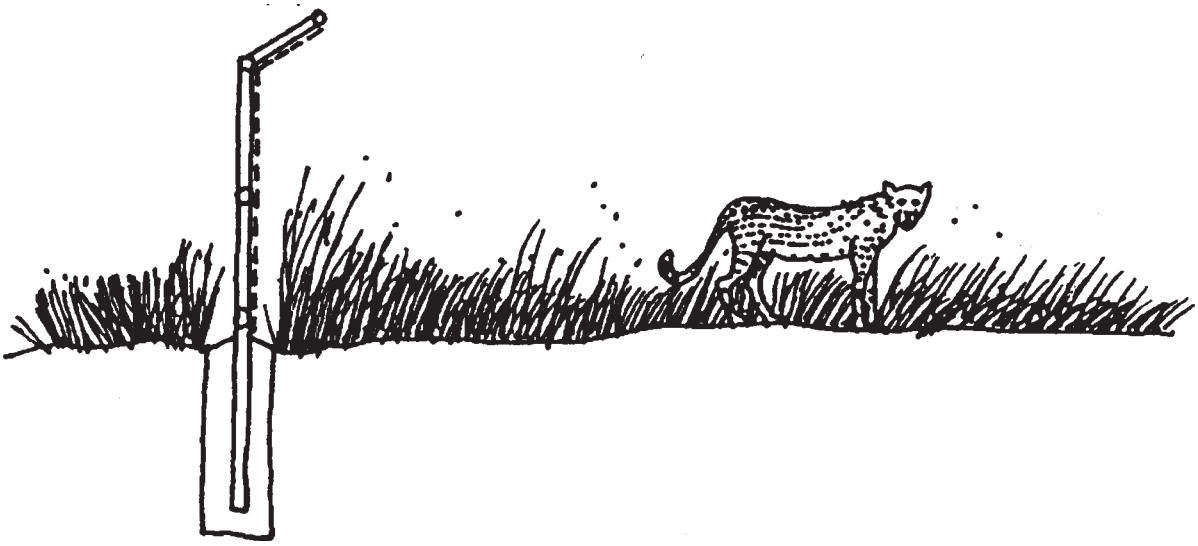


Fig.14. Illustration showing use of mesh fence with overhang.

Fig.15. Open top enclosure using overhang with inclined inward and welded steel plate on chainlink mesh fence as a barrier for leopards at Himalayan Zoological Park, Gangtok.

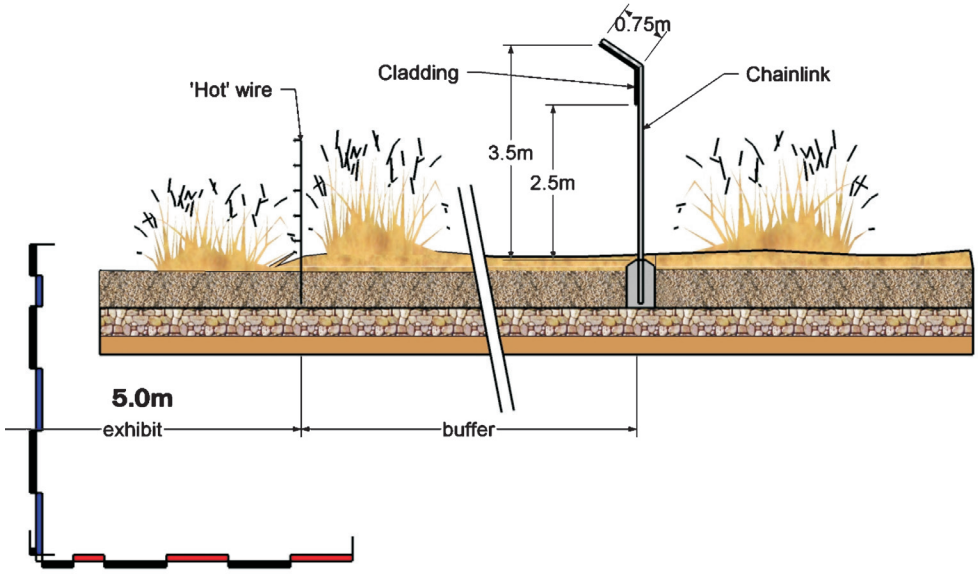
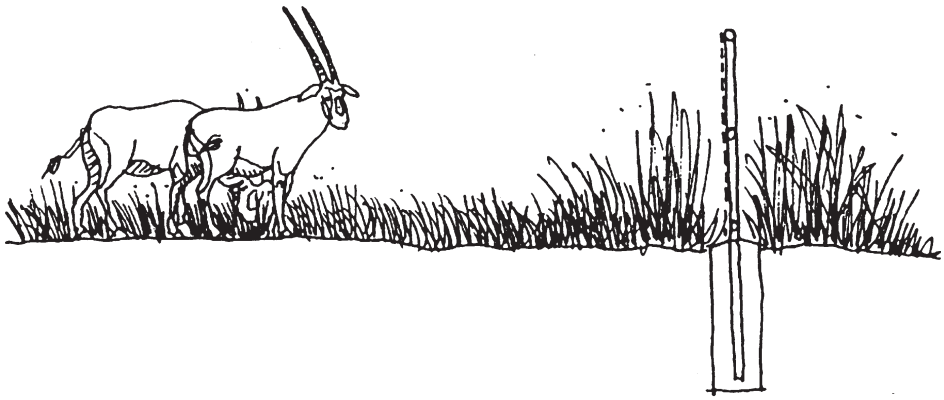


Fig.16. Mesh fence with overhang for bears.

Fig.17. Illustration showing the use of verticial fence as barrier.



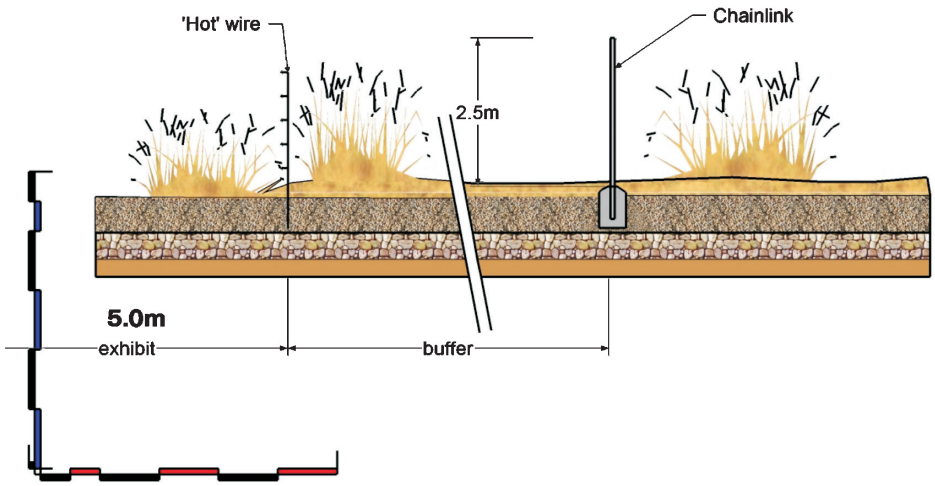


Fig.18. Cross section showing the use of vertical fence.

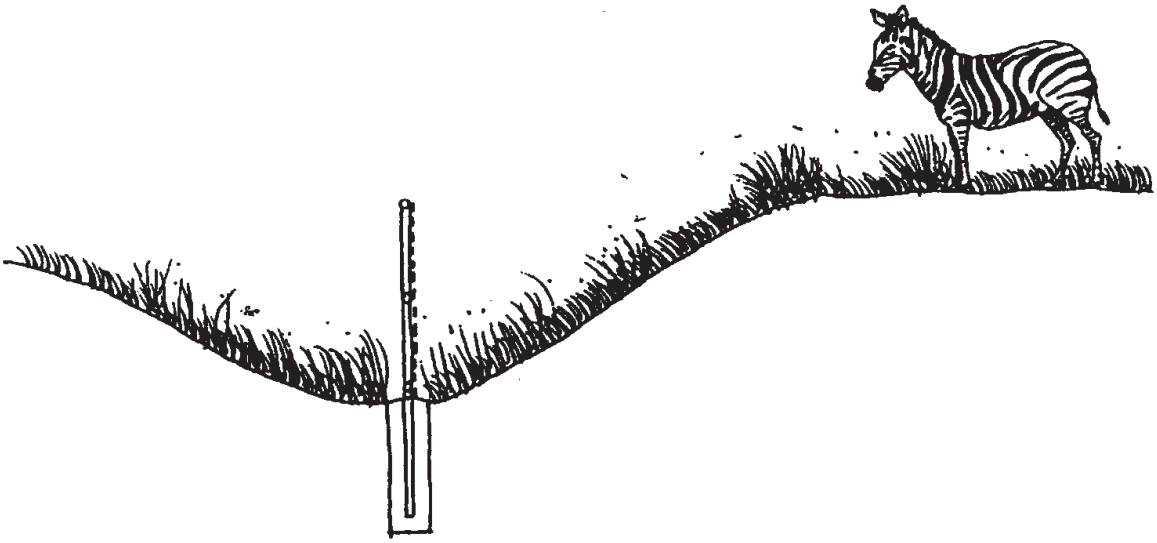


Fig.19. Illustration showing depressed vertical fence barrier.

Fig.20. Zebra enclosure with depressed vertical fence.

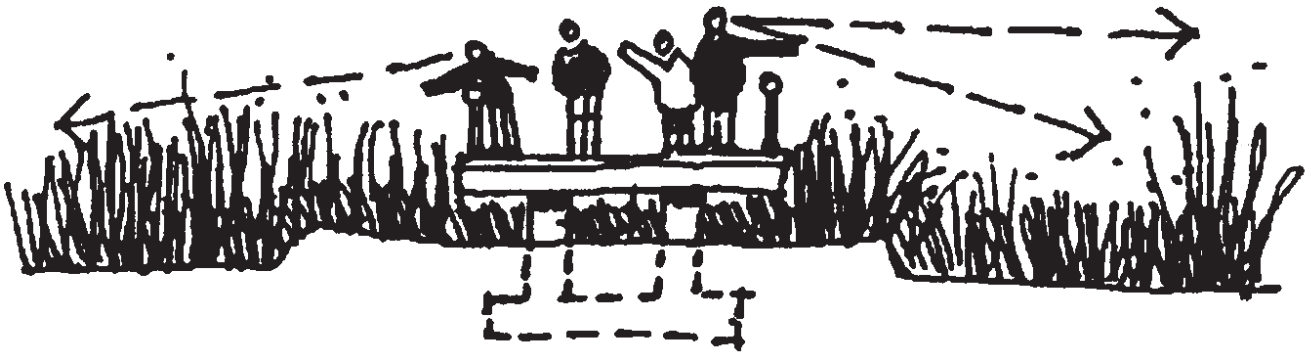
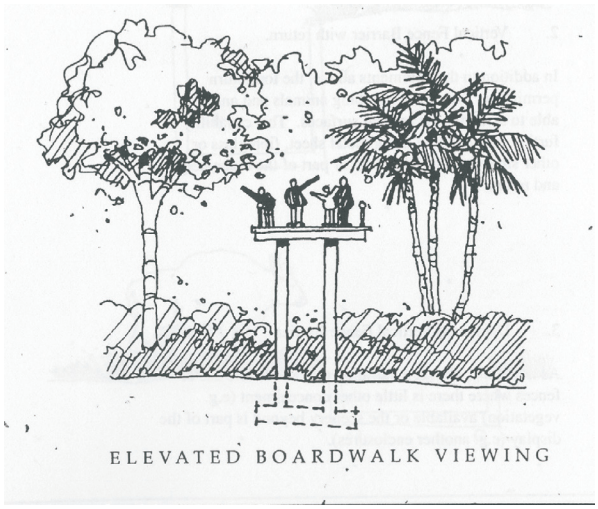


Fig.21. Illustration showing boardwalk walk-thru viewing.

Fig.22. Boardwalk viewing at San Diego Zoo, San Diego.



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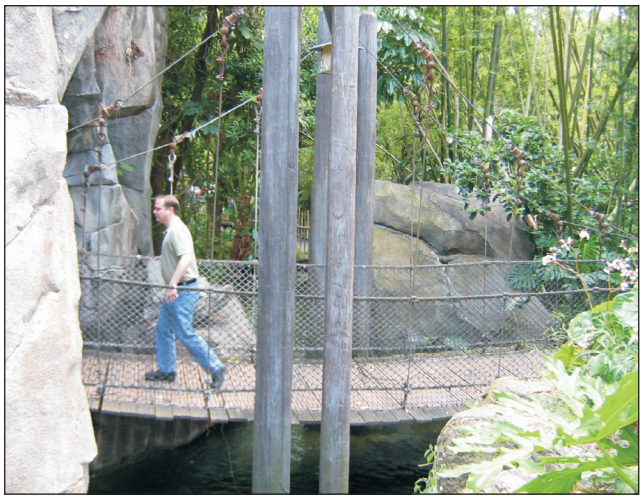


(26)

Fig. 23, 24, 25 & 26. Showing the examples of elevated boardwalk as barrier.

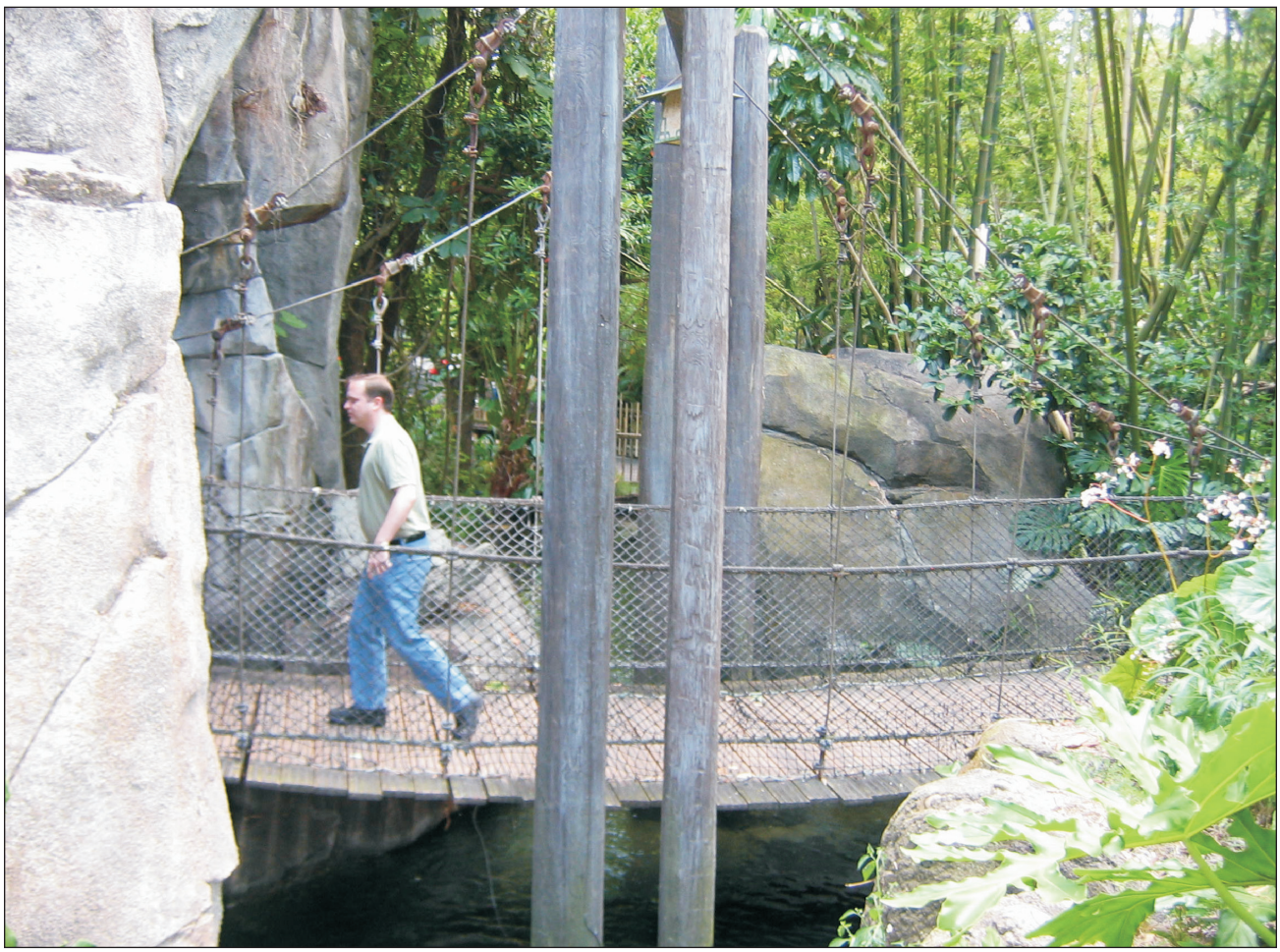


Fig.27. Use of hanging bridge as barrier at Disney Animal Kingdom, Orlando, USA.

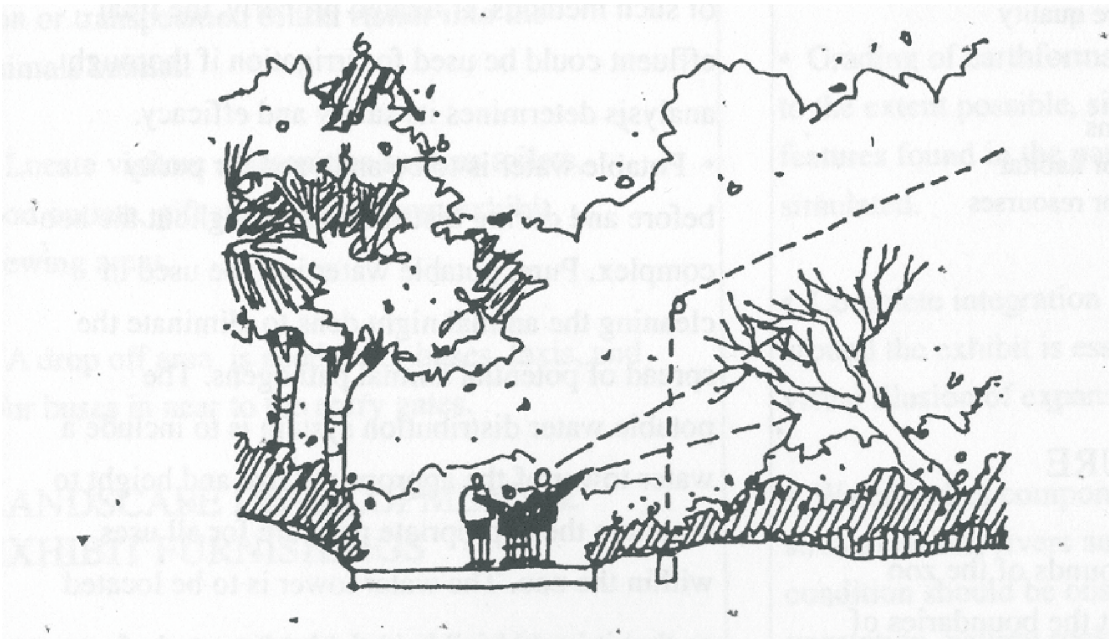


Fig.28. Illustration showing viewing through mesh.

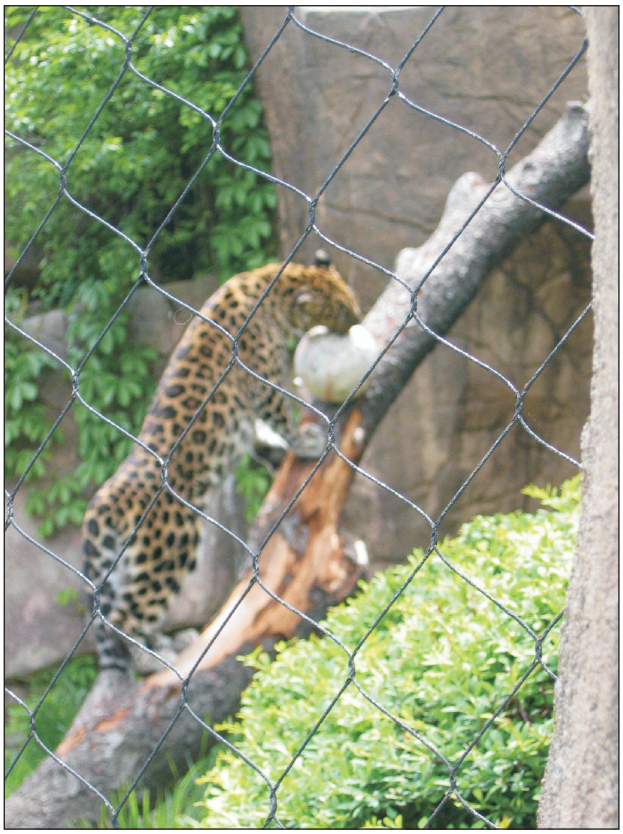


Fig.29. Leopard enclosure at Brookfield Zoo, Chicago using the galvanized steel mesh as barrier.

(30)

Fig.30, 31. Illustration showing viewing through piano wire as a barrier at reptile exhibit at Jersey Zoo, Jersey.

(31)

Fig.32. Close up of the piano wire.

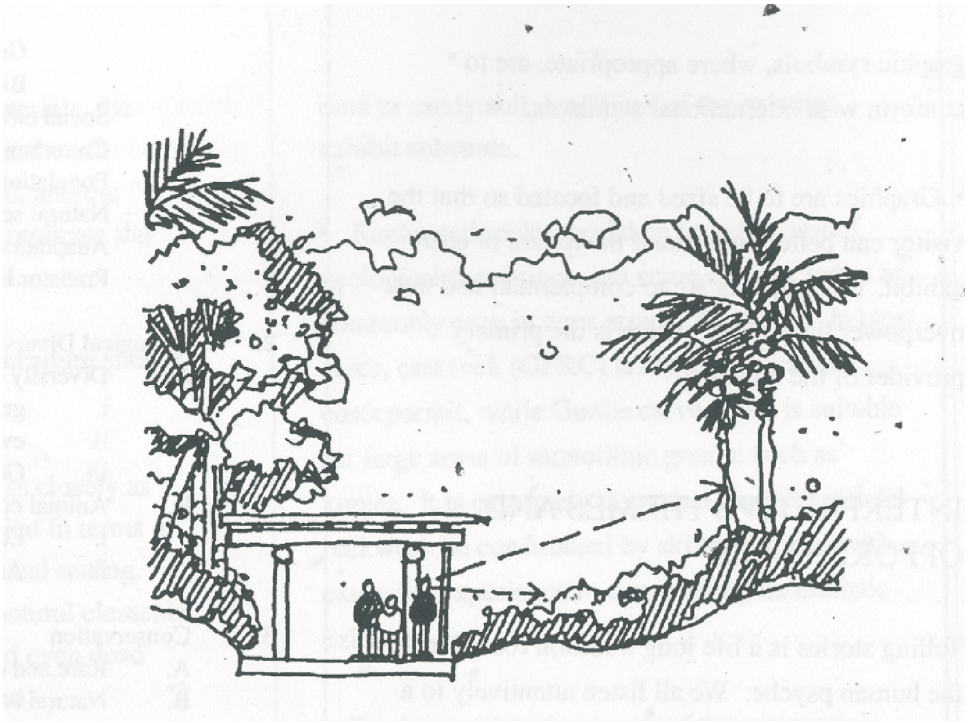


Fig.33. Illustration showing glass viewing with structure.

Fig.34. Glass viewing exhibit for primates at Melbourne Zoo, Australia.

Note : The visitors image reflection on the glass. The same should be avoided by installing the glass properly.

Fig.35. Viewing animals in Safari Parks through the glass window generates great exitements among visitors.

Fig.36. Glass viewing exibit for smaller cats are easy to install as well as provide unhidered viewing to the visitors.

Fig.37. Example of glass viewing at Melbourne Zoo, Australia.

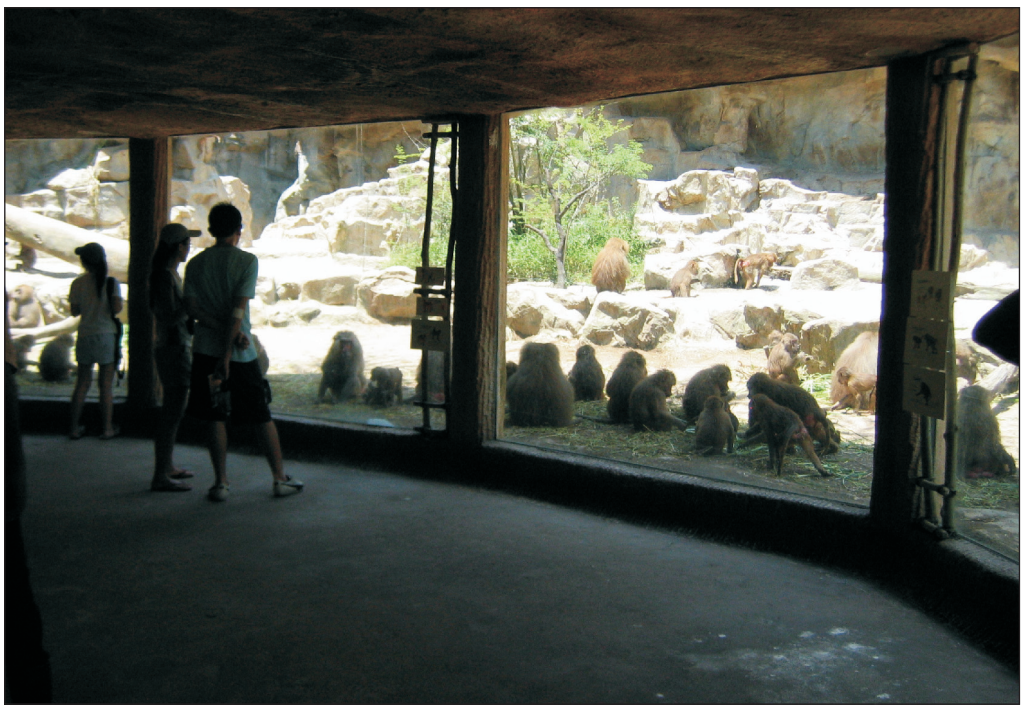


Fig.38. Glass viewing exhibit for Baboons at Singapore Zoological Gardens at Singapore.

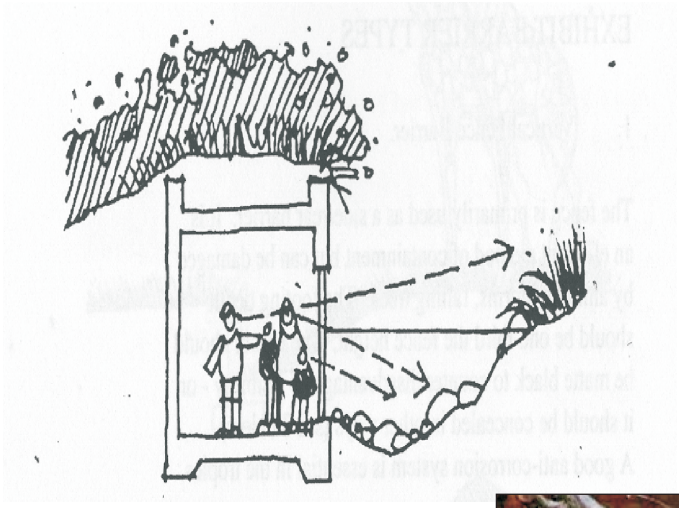


Fig.39. Illustration showing viewing through glass.

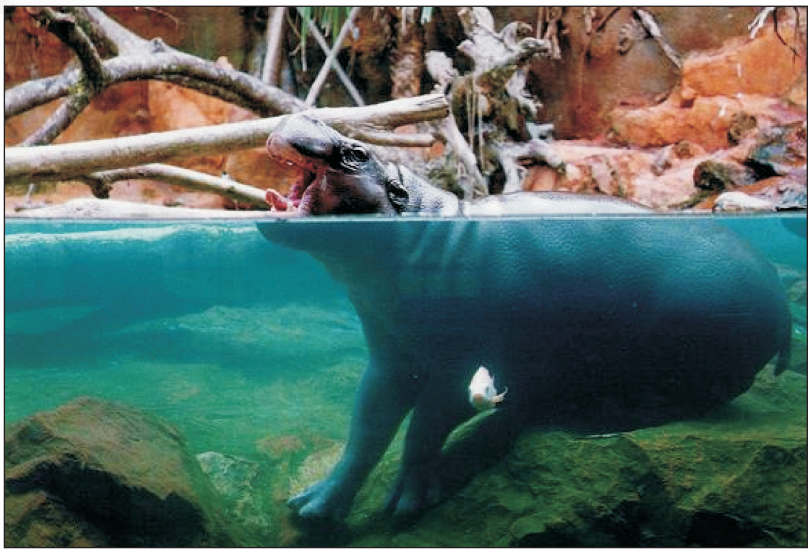
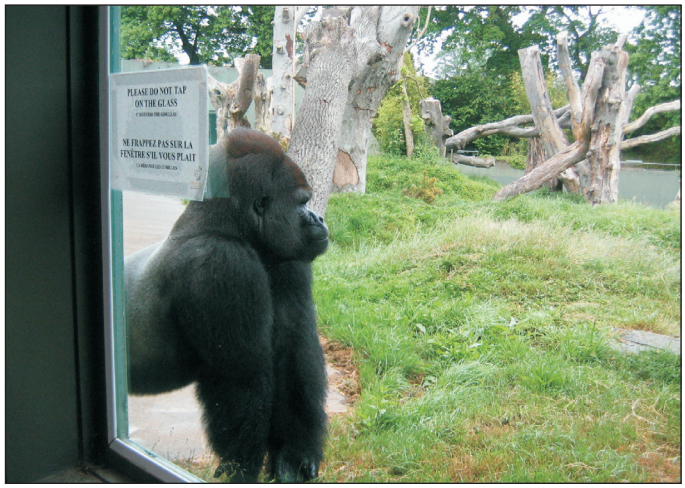


Fig.40. Under water glass viewing exhibit for Pigmy Hippo at Singapore Zoological Gardens, Singapore.

Fig.41. Under water glass viewing exhibit for smaller mammals at London Zoo, London.



(42)

(43)

(44)

Fig.42,43 and 44. Examples of glass viewing at Jersey, Melbourne and London used for exhibiting Gorillas, Bats and smaller mammals.

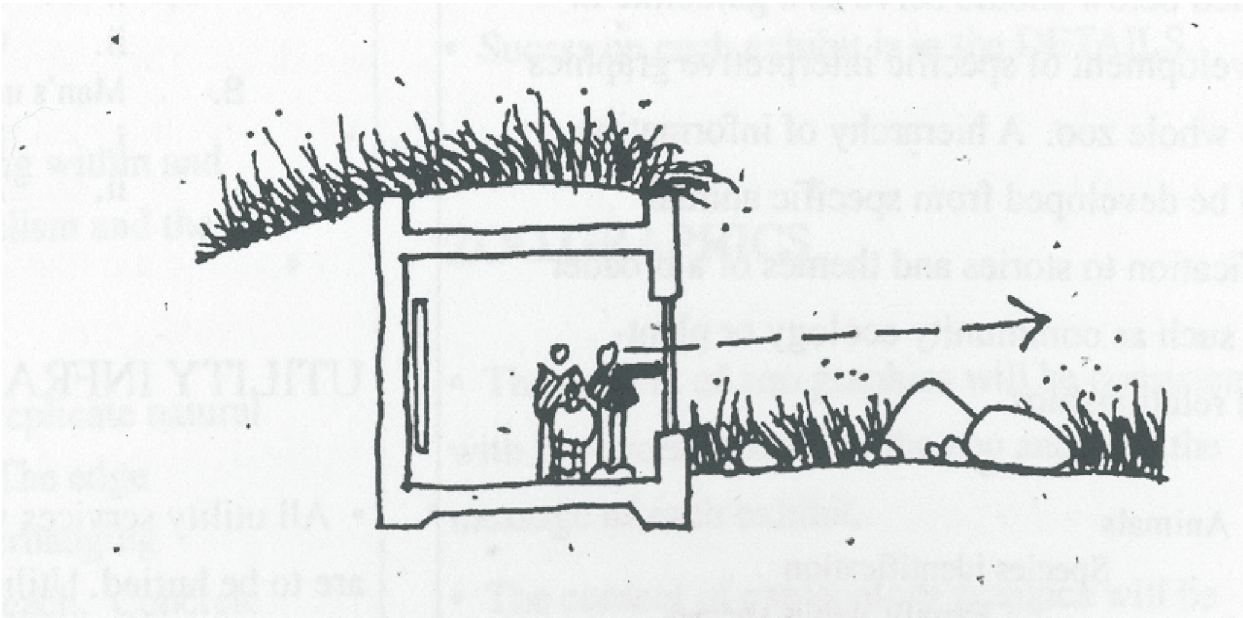


Fig.45. Illustration showing bunker viewing.

Fig.46. Viewing rodents through glass window at Brookfield Zoo, Chicago.

Fig.47. Pop up viewing exhibit for Giraffe.

Fig.48. Pop up viewing exhibit for agile animals.

Fig.49. Elephant exhibit at Melbourne Zoo provided with the shaded structure for visitors relax and watch animals, at the same time these structure serve as a viewing galleries.

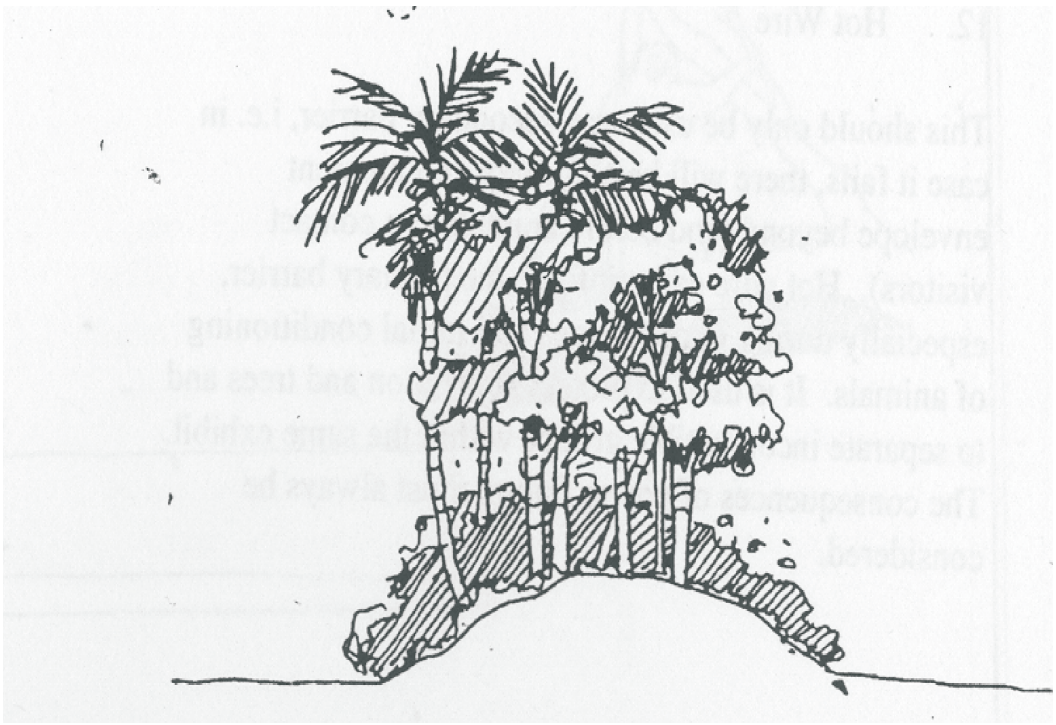


Fig.50. Illustration showing the use of psychological restraint.

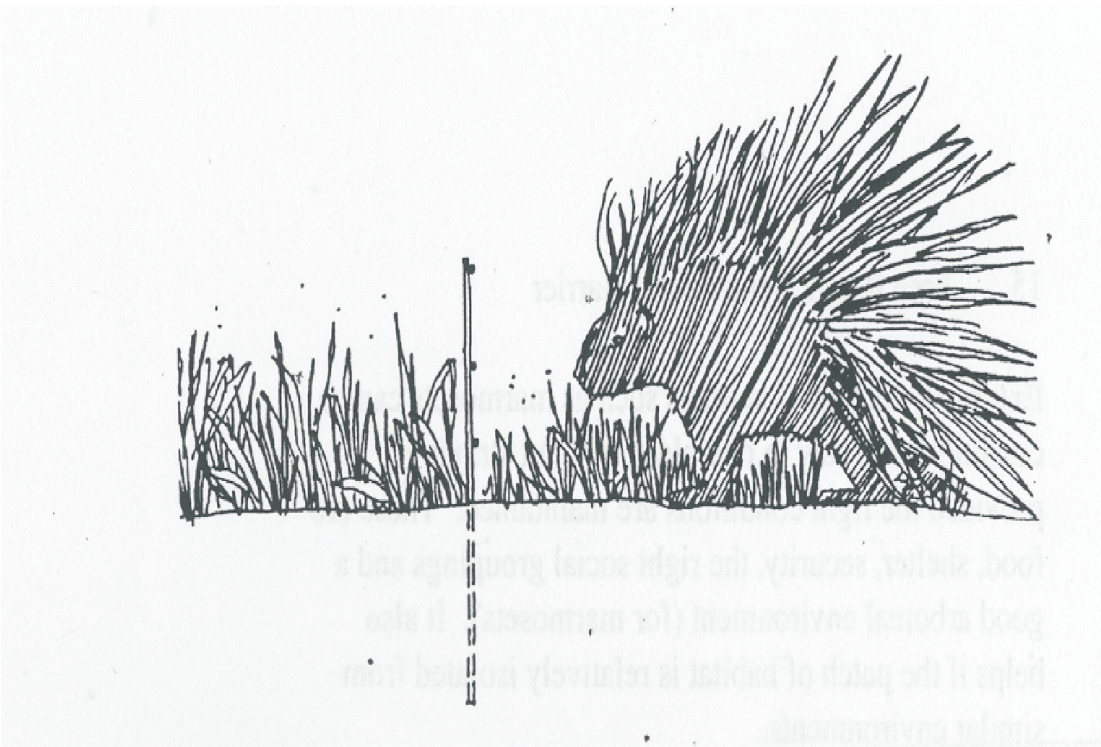
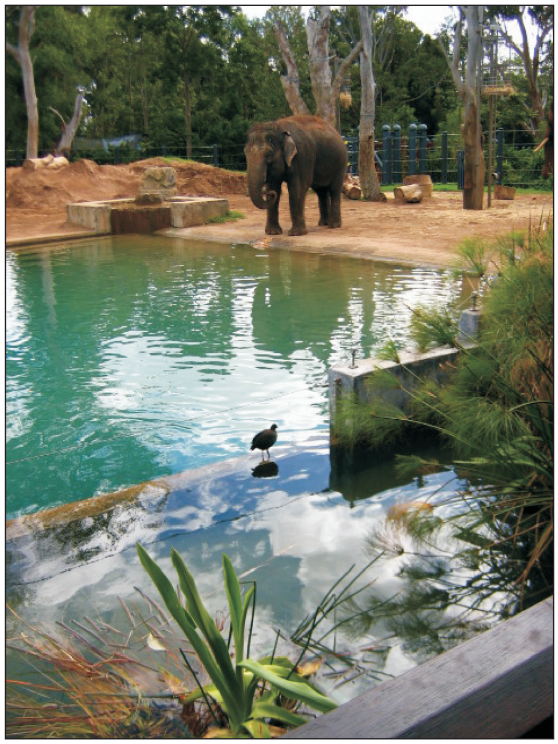


Fig.51. Illustration showing the use of hot wire.



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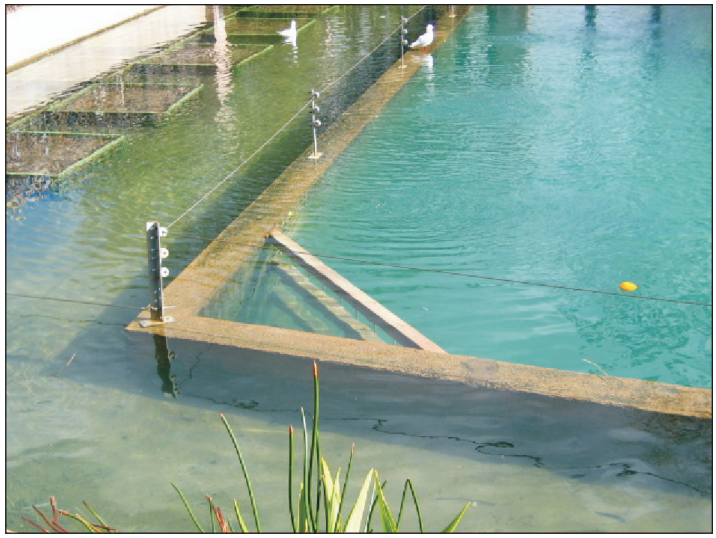

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Fig.52 and 53. Elephant enclosure using hidden barrier and hot wire.

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Fig.54 & 55. Use of hot wier (power fence) for primates.

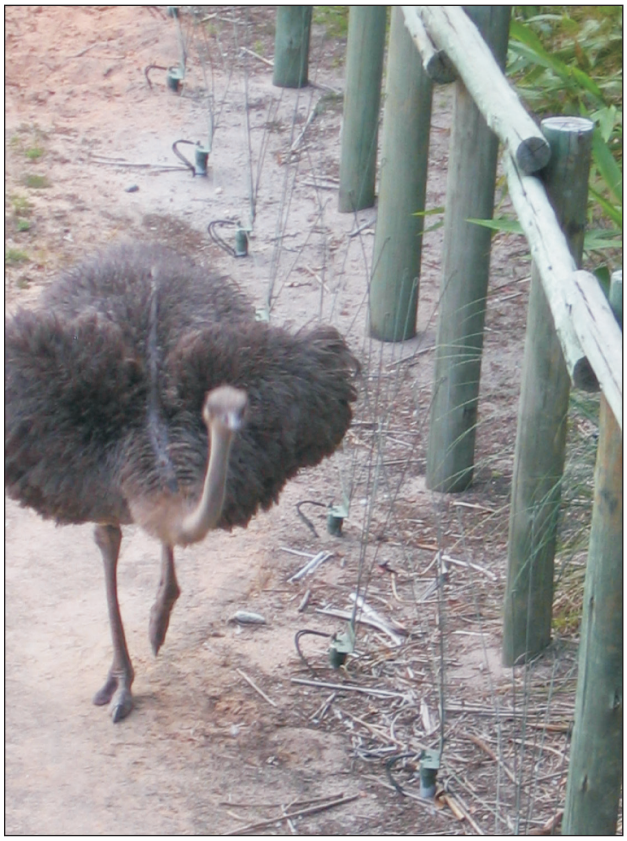

Fig.56. Use of crown type power fence for Ostrich at Disney Animal Kingdom, Orlando, USA.

Fig.57. Use of power fence at Singapore Zoo keeping away the primates from the water bodies.

Fig.58. Barbary macaque enclosure at Jersey Zoo using power fence as a barrier.

Fig.59. Hyena enclosure at Rajiv Gandhi Zoo, Pune using power fence as a barrier.

Fig.60. Sloth bears housed at Agra Bear Rescue Facility at Agra using power fence.

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Fig.61 & 62. Use of wooden sleepers (railway sleepers) as barrier for housing elephants at Whipsnade Wild Animal Park, UK.

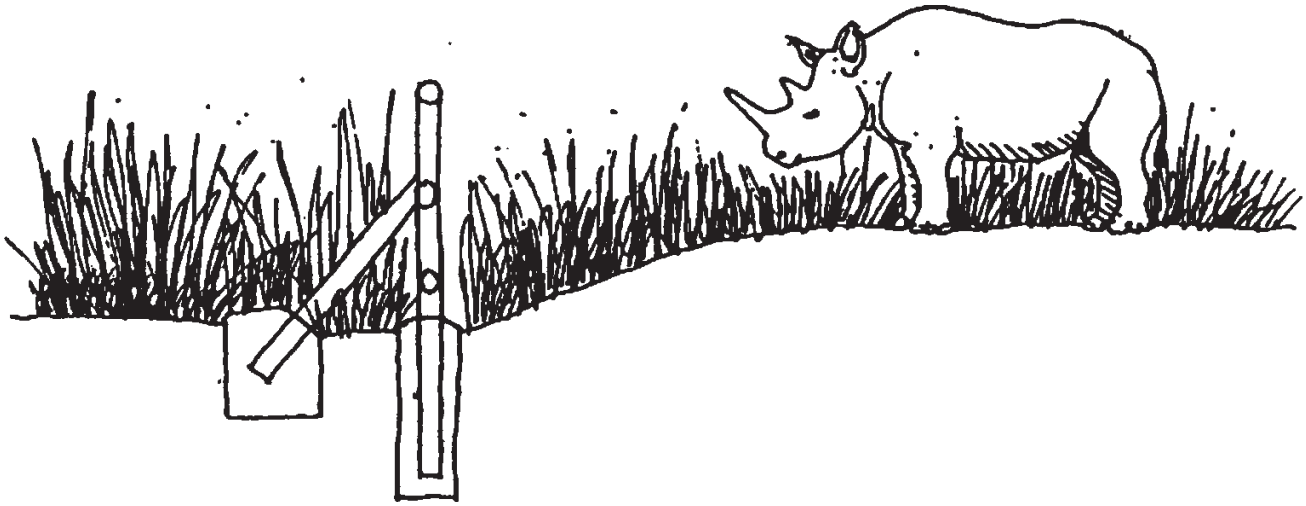

Fig.63. Illustration showing reinforced pipe as a barrier.

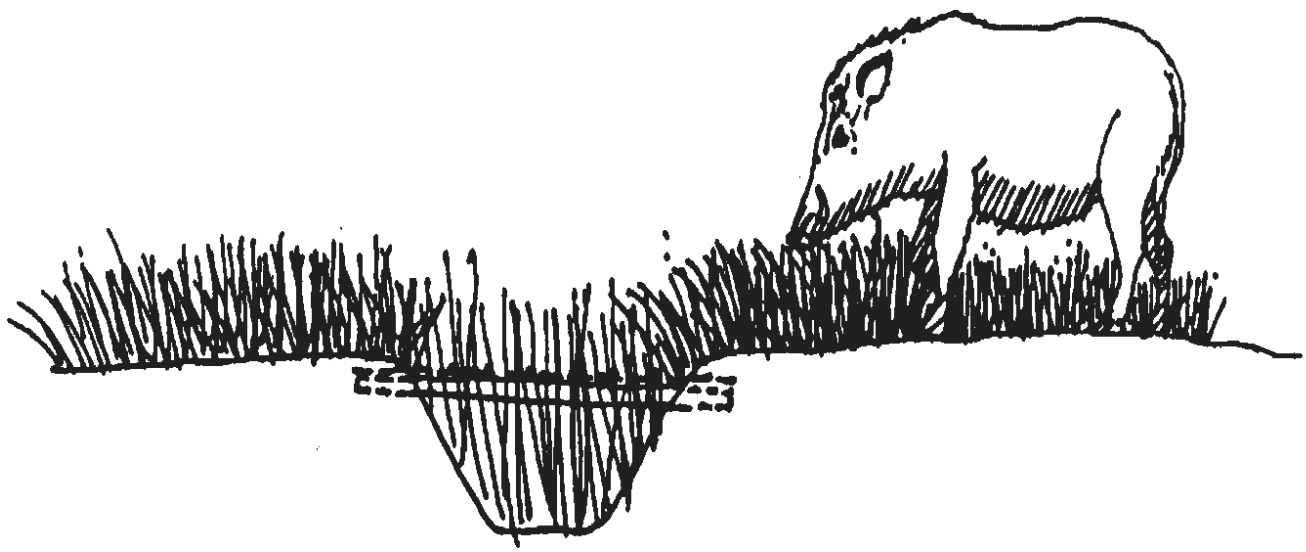

Fig.64. Illustration showing horizontal fence as a barrier.

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Fig.65 & 66. Examples of walk-thru aviary.

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Fig.67 & 68. Aviary for vultures at London Zoo using piano wire/string as a barrier.

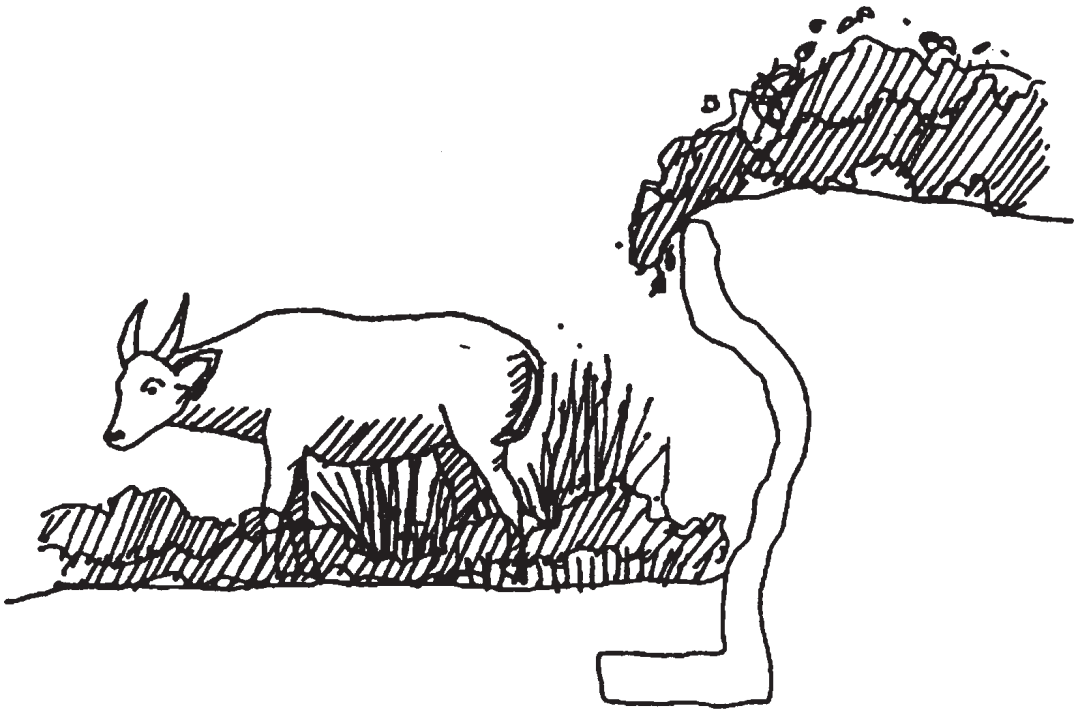

Fig.69. Illustration showing Wall as a barrier.

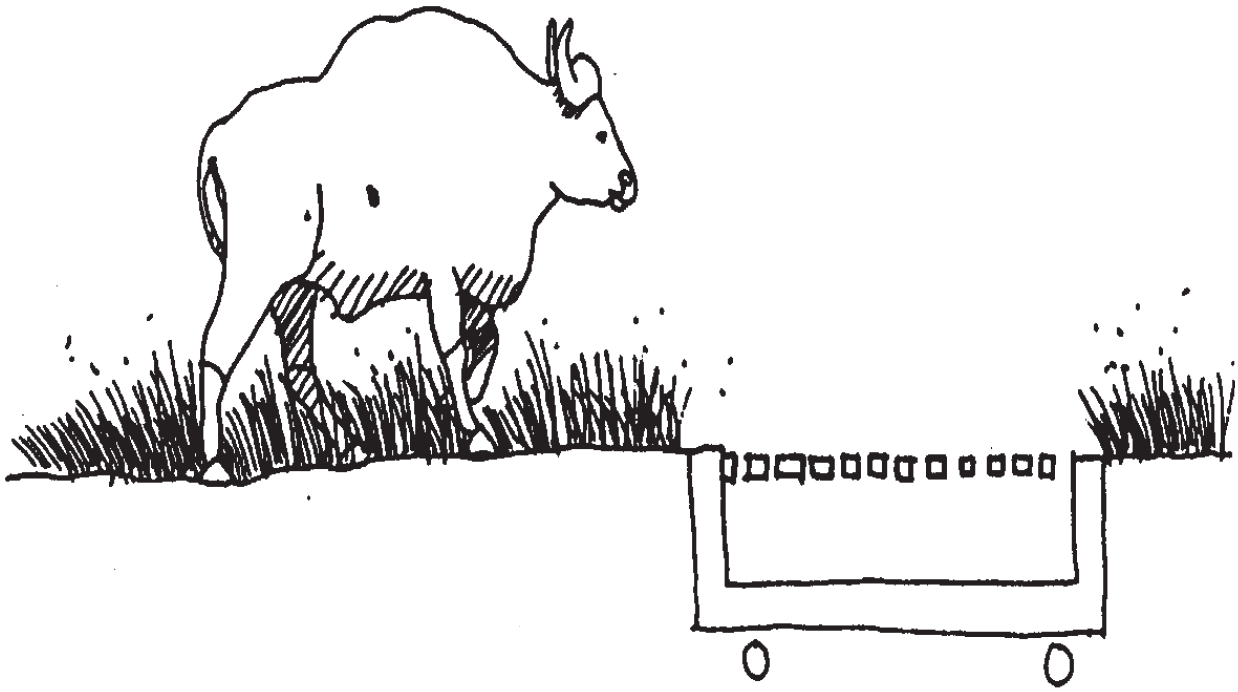

Fig.70. Illustration showing Cattle grid used as a barrier for housing Gaur and other antelopes.

Fig.71. Open enclosure used for housing large reptiles provided with the wire netting to keep away the predators such as kites and eagles at Jersey Zoo, Jersey.

Fig.72. Use of electrical barrier-walk-through.

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Notes

Congratulation to the Central Zoo Authority of India and to Dr. Brij Kishor Gupta for providing these Guidelines For Barrier Design. Readers should pay special attention to the reasoning behind the guidelines such as to increase visitiors respect and admiration for animals and to lower the animal stress by physically placing animals at higher elevations than visitiors and thus encouraging visitiors to literally 'look up to the animals. This not only increases the drama of encounter, but properly done, begins to recreate the experience of meeting the animals in the wild. This is the essence of "Habitat Immersion" exhibit design.

While the barrier recommendations given in this book will useful in both auditing existing facilities for safety and appropriateness and for the design of new facilities, readers must remember these dimension often represent minimum proven barriers. As the overall quality of animal care, nutrition and physical fitness improves in zoo, animal size and strength is also like to improve. A Barrier that proved adequate for the past and current zoo animals may no longer be sufficient to met the challenge of future generations of highly fit and motivated tigers for example. This was tragically proven recently at San Francisco Zoo in the USA were a barrier that had been adequated for sixty years was no longer sufficient to prevent a Siberian tiger from escaping and killing a bystander. Each zoo must accept full responsibility for the adequacy and appropriateness of its exhibit designs and management, no matter, what the source of the information it receives. That said and acknowledged, this book will take a valuable contibution to the improvement of Zoos in India and Internationally:

Jon Coe, International Zoo Design Consultant
Author of over 50 papers on Zoo Planning and Design

ABOUT THE AUTHOR

Brij Kishor Gupta, obtained doctorate degree studying behaviour and environmental enrichment among captive Sloth bears. Dr. Gupta has fifteen years of experience working with wildlife, zoos and rescue centre in wildlife conservation, ex situ breeding, zoo planning, design and management. He received specialised training and was later grantee and Fellow of the Durrell Wildlife Conservation Trust and Smithsonian Institution. He also received PETA's 2007 Proggy Award for Animal Welfare Scientist. He has contributed sixty-six scientific papers to various national and international journals. He has authored a book on "Captive Care of Common Indian Frogs and Toads" and he was on the editorial board of the "Master Planning of Zoos", a proceedings published by the Central Zoo Authority. Dr. Gupta is presently working as Evaluation and Monitoring Officer with the Central Zoo Authority (a statutory body under the Ministry of Environment & Forests, Government of India) at New Delhi, India.