In designing facilities to maximize rhino health and reproductive success, it is important that the captive environment resemble the natural environment as closely as possible. (For more detailed information on the natural habitats of the various rhino species, see the Taxonomy and Conservation Status chapter.) The species to be exhibited will dictate the design of rhino facilities, as species differ in their group compositions and enclosure requirements. Additionally, whether an institution wishes to maintain exhibit-only or breeding individuals will act as a determining factor in the design of rhino enclosures. Whenever possible, institutions are encouraged to plan for breeding capabilities, but the various SSP Coordinators and Rhino TAG chairs recognize the educational need for display-only exhibits. These exhibits serve the rhino conservation effort by holding non-reproductive and single-sex specimens. The following section outlines design considerations for indoor and outdoor rhino facilities, as well as aspects of chute design for rhino restraint.

Enclosures

The design of captive enclosures for rhinos requires an understanding of rhino biology, behavior and social organization. As previously stated, black, white and greater one-horned rhinos vary in their levels of sociality and thus have different housing requirements. Tables 15 and 16 list the recommended animal numbers for institutions holding rhinos (See also the Management and Behavior chapter.) and the enclosure types recommended depending on institutional goals. It is important to note that for the most part, exhibit and holding-space availability will dictate an institution's designation as either a breeding or an exhibit facility. Design elements for a breeding facility should include an outdoor primary enclosure (with separation capabilities), indoor holding and an isolation area. Additionally, breeding institutions must have space for any offspring to be held for up to 3 years of age. Exhibit-only facilities should have an outdoor primary enclosure and indoor holding areas (both with separation capabilities). It will be recommended that exhibit-only facilities receive pre- or post-reproductive-age or single-sex groups of surplus animals.

In general, it is recommended that enclosures be designed such that animals may be kept outdoors as much as is possible within the following temperature constraints. Rhinos should not be locked outside when the temperature is below 4.4° C (40° F); sun, wind chill and rain should be considered in calculating temperature. During extremely cold weather, rhinos should not have access to pools or mud wallows; pools should be drained and mud wallows filled with substrate. Animals should not be let out if enclosures are icy. Temporary exposure to temperatures below 4.4° C (40° F) for cleaning is left to the discretion of management. Localities that experience average daily temperatures below 10° C (50° F) (average of high and low temperatures over a 24-hr period), should provide heated facilities capable of maintaining a minimum temperature of 13° C (55° F).

TABLE 15. Recommended numbers for institutional holding

Rhino species	Recommended minimum groupings for breeding[a]	Preferred optimal holding for a breeding institution	Exhibit only (per institution)
Black	1.1	2.2 (2 pairs)	1.1 or 0.2
White	1.2	2.4 (1 herd/ 1 back-up male)	1.1 or 0.2[b]
Greater one-horned	1.1[c]	2.2 (2 pairs)	1.1[c] or 0.2

[a] Breeding institutions must have space for offspring to be held for up to 3 years following birth.

[b] Multi-male bachelor groups have been maintained in very large enclosures.

[c] In the case of greater one-horned rhinos, males and females should be introduced only during the female's estrus period. Institutions with very large enclosures (e.g., San Diego Wild Animal Park) may be able to hold opposite-sex animals together consistently.

The design of rhino enclosures depends on the species, the type of rhino program (exhibit-only or breeding) and the number of animals. In all cases, the larger and more varied the enclosure, the better. (*Photo: Oklahoma City Zoological Park*)

OUTDOOR HOUSING

Several general outdoor enclosure designs are recommended that incorporate the data available on the behavior and ecology of wild black, white and greater one-horned rhinos. As previously described, rhinos of all species are considered to be less solitary than was originally thought. Given very large yards or ranch situations, even opposite-sex greater one-horned rhinos (considered the least social of the commonly held rhino species) may be housed together. For the most part, however, rhinos are considered somewhat territorial; therefore, more than one outdoor yard is strongly recommended. To provide a large area for introductions of black and greater one-horned rhinos, a communal yard adjacent to individual yards should be available. If the space is not available, two adjacent yards may be opened for male/female introductions. In many respects, the critical enclosure characteristic is the availability of escape routes and visual barriers, which serve to hide or prevent access to a pursued animal. Gates may be used as escape routes, provided that care is taken to prevent dead-end corners and create run-arounds so that an animal can enter or leave the yard without an aggressor blocking or guarding the only exit.

Enclosure size depends on whether rhinos are kept for exhibit-only or breeding purposes (Table 16). It should be noted that a calf is considered an adult with respect to minimum space requirements after weaning; this fact should be considered in determining minimum enclosure size. Institutions should expect to hold offspring until they reach 3 years of age.

Primary Barriers

The barrier between rhinos and the viewing public is a critical element in the design of the outdoor exhibit. This primary barrier should allow visitors a clear view of the animals from a safe location. Many types of primary barriers are available, the most common of which are walls, fencing, dry moats and water moats. One consideration in choosing fence type should be the size of the enclosure. For example, smaller exhibits should be constructed with barriers that provide as much visual exposure as possible.

Fencing

Because any of the rhino species may climb, a primary barrier should be a minimum of 1.5 m (5 ft) high and non-climbable. Within small enclosures, particular attention should be given to the climbing ability of rhinos and to the need for separating aggressive animals. A secondary barrier or a taller primary barrier may serve to counter these problems.

Recommended materials for primary fencing include solid concrete or rock walls, horizontal pipe or cable spaced 25 to 30 cm (10 to 12 in.) apart and vertical pipe or posts spaced 25 to 30 cm (10 to 12 in.) apart. Note that cable should be used only for horizontal fences. The size of the exhibit to be fenced will determine the strength and type of fencing material used, as each type has both advantages and disadvantages. Concrete surfaces and bare steel cable create surfaces that may encourage rhinos to horn-rub excessively, causing abnormal horn wear. Whenever necessary, surfaces should be covered with a non-abrasive material. Inserting the cable through plastic pipe or hose can prevent this problem, and concrete surfaces can be covered with non-toxic wood.

TABLE 16. Recommended enclosure types and sizes for captive rhinos by species [in sq m and (sq ft)]

	Individual Holding (per rhino)		Exhibit Only (per rhino)		Breeding/Communal	
	Indoor	Outdoor	Indoor (as primary exhibit area)	Outdoor	Indoor	Outdoor
Black	18 (200)	186 (2,000)	204 (2,200)	771 (8,300)	not recommended	2,322 (25,000)
White	30 (320)	186 (2,000)	215 (2,320)	929 (10,000)	not recommended	2,787 (30,000)
Greater one-horned	30 (320)	186 (2,000)	215 (2,320)	929 (10,000)	not recommended	2,787 (30,000)

1 (*Photo: Knoxville Zoological Gardens*)

If poles are used, each should be approximately 30 cm (12 in.) in diameter and set in concrete with approximately 1.8 m (6 ft) underground. Poles should be spaced as closely together as possible to prevent rhinos from getting their horns through and uprooting the fence. *Creosote-treated poles, which are dangerous to rhinos, should not be used.*

It is important to consider fence spacing and keeper access/exit in the event of an emergency. Rocks or a rock apron can be utilized to protect the poles or other objects in the exhibit from damage. A rock apron should extend 1.8 m (6 ft) from the leading edge of the object to offer adequate protection. If small rocks are used, they should be several layers thick; otherwise, a single layer of very large rocks is probably adequate.

Dry Moat

The use of a dry moat requires one vertical wall, which should be a minimum of 1.5 m (5 ft) high, located on the public side. The second wall should be sloped at a maximum of 30° so that the animals can climb out. This gradual decline of the exhibit substrate down to a solid wall can be used to create a moat effect, but *ditch moats with two vertical walls are considered dangerous to rhinos and are not recommended.* The floor space in the moat should be a minimum of 1.5 m (5 ft) across to prevent rhinos from being trapped, and surface substrate for the moat should provide stable footing. (Recommended materials include dirt, gravel, sand, etc.)

Water Moat

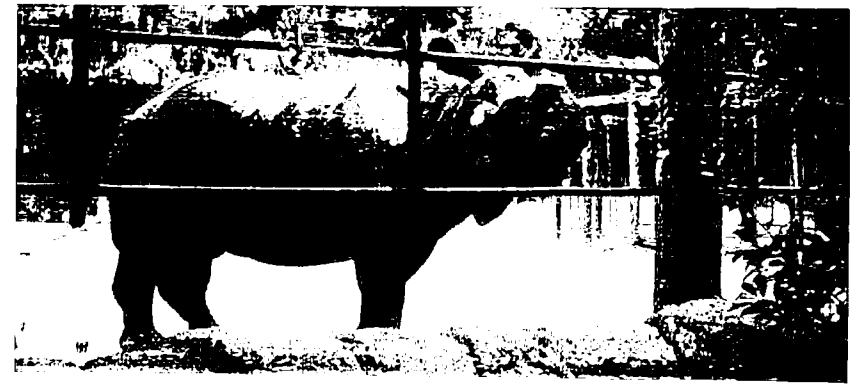
Water can be utilized as a primary barrier, although it carries the risk of drowning or injury, especially for calves. Dimensions and specifications for a water moat should be the same as those listed above for a dry moat. Pools may also serve as primary barriers, provided the walls are high enough [at least 1.5 m (5 ft) high] to prevent animals from climbing out. Once a rhino has its chin over the top of a wall, it can get its front feet over as well.

Secondary Barriers

Though not critical to the design of outdoor enclosures, secondary barriers may protect exhibit features or lessen stress on primary barriers. Recommended types are butt rails, vertical poles and electrically charged, or "hot," wire. Plantings can also serve as a secondary barrier when used to create a visual screen. For example, the use of plantings that extend above a low wall can give the appearance of a bigger wall [though the primary barrier height minimum of 1.5 m (5 ft) still applies]. Electric fencing can be used to deter animals from destroying plantings, trees and other secondary barriers. Rock aprons may also be used around trees and fence lines as secondary barriers.

Gates

Enclosure gates can be the weakest points of the exhibit; therefore, adequate hinge and lock strengths are very important. Interior doors are usually constructed of heavy-gauge galvanized steel or pipe that is hinged or sliding. Sliding gates are optimal, as they may be partially opened, and should be a minimum of 1.8 m (6 ft) wide and 2 m (6 ft 8 in.) high. If the gate uses a track, care should be taken in the construction of the track to avoid injuring the feet of the animals as they run through gates during introductions. Exterior building doors



2 (*Photo: Fort Worth Zoological Park*)

3 (*Photo: Fossil Rim Wildlife Center*)

4 (*Photo: Fort Worth Zoological Park*)

Primary fence options for rhinos vary. Depending on the type of exhibit, one type may be more suited than another. Walls (1) may be effective in exhibits that are viewed from above. Cables (2) are particularly effective for exhibits in which the visitor is on equal footing with the rhino. Another option in this case is a more typical fence structure (3). Water moats (4) can be effective also, though a secondary barrier is recommended and care should be taken when calves are in the exhibit.

are usually made from wood reinforced with steel, with the lower part covered by a steel plate to minimize damage. Gates should be constructed to allow keepers to open and close them without entering rhino space. Also, where appropriate, vehicle access to an enclosure should be provided.

Substrate

The outdoor enclosure should have a well-drained surface that provides adequate footing for rhinos. Greater one-horned rhinos require substrates that "give," including mulch (such as hardwood), grass (Irrigation should be planned for all natural areas if needed.) and bedding because of the incidence of foot problems. Black rhinos should be maintained on grass if the space is available, but limestone is adequate. Substrate options for white rhinos include grass, limestone, sand and other natural materials in combination. For example, one institution reported an outdoor enclosure substrate composition of 75% grass and 25% sand, rocky areas and decomposed granite. Rhinos should be carefully observed upon introduction to a new substrate, as excessive ingestion of the substrate from feeding on the ground has caused impaction in other rear-gut digesters.

Water

Fresh, potable water should be available at all times. Water should be changed daily or supplied by an automatic-fill or continuous-flow device. Regular cleaning and disinfecting should occur at a rate that inhibits the growth of algae and bacteria. Water devices should be substantially constructed to prevent injury, upset, spillage or leakage.

Mud Wallows

All rhinos need access to pools and/or mud wallows for skin health, temperature regulation and behavioral enrichment. The size of mud wallows should be gauged by the number of animals in the exhibit to allow ample room for each individual. It should be noted that given a start, rhinos may construct their own mud wallows. Mud wallows should be renovated periodically to prevent contamination.

Pools

Pools constructed in rhino enclosures should be of approximately equal dimensions (length x width). When a calf is in the enclosure, pools should be modified or drained to a depth of 0.45 m (1.5 ft) or less. For entry into the pool, ramps are preferable to steps. They should be placed in at least two or three locations around a pool, if not the entire perimeter, to ensure safe access in and out of the pool. Ramp slopes should be no greater than 15 to 20°. If steps are used rather than ramps, they should have a 20- to 25-cm (8- to 10-in.) rise with a 41- to 61-cm (16- to 24-in.) step. Note that multiple entries to a pool prevent it from being a "dead end" in the enclosure. In the design of slopes or steps, keeper access for cleaning should be considered. The pool substrate should be broom-swept concrete. Table 17 lists pool specifications by species.

Visual Barriers

When rhinos are maintained together in a more herd-like situation, naturalistic visual and physical barriers (refuges) in an outdoor enclosure may help decrease aggression by permit-

1 (Photo: San Diego Zoological Society)

TABLE 17. Specifications for exhibit pools by species

	Overall Size	Depth	Comments
Black	13.9 sq m (150 sq ft)	0.3 to 0.9 m (1 to 3 ft)	Optional; rarely used except in warmer regions
White	37.2 sq m (400 sq ft)	0.4 to 1.5 m (1.5 to 5 ft)	Recommended
Greater one-horned	37.2 sq m (400 sq ft)	at least 0.9 m (3 ft); optimally 1.5 m (5 ft)	Recommended

ting animals to separate themselves from others if necessary during introductions or in a group situation. Barriers should be large and high enough to provide "safe zones" that allow an animal to pass from another's sight but should not hinder public viewing. Types of visual barriers include deadfall, logs and run-arounds (boulders), as well as trees and natural plantings. Trees and plantings may be protected from rhinos by pipe caging, rock aprons or barrier fencing. If permanent physical structures are not available as barriers, dirt mounds may be used to give individuals additional visual barrier points in the enclosure.

Shade/Rain Shelter

Access to shade is a necessity as well as a USDA requirement under the Animal Welfare Act. A variety of both natural and constructed options is possible. It is recommended that rhinos have access to a shaded area during daylight hours. It is also important that a shade option be adequate as a rain shelter if barn shelter is not always accessible; therefore, trees may not be completely adequate. Because some species use pools heavily, pools should be located in areas that are shaded at least part of the day.

Additional Furnishings

Additional furnishings for the outdoor exhibit should include scratching posts, which may be particularly effective if placed near mud wallows or pools. Post material must be non-toxic to rhinos (i.e., non-creosote). Several institutions have buried deadfall or logs upright in concrete sewer culverts, which are routed in place with 0.9 to 1.2 m (3 or 4 ft) of gravel. This enables managers to remove and replace posts as they rot. In addition, feed should be available at all times in the form of browse feed stations and mineral salt licks.

INDOOR HOUSING

Indoor housing is recommended for additional separation capabilities (beyond the primary enclosure) and is critical for those institutions in colder latitudes. At no time should rhinos be subjected to temperatures below freezing; animals should have access to radiant heat if needed. An indoor facility in the winter should be heated to a minimum of 13° C (55° F) with the capability of maintaining some areas of the barn at 23.9° C (75° F).

The humidity level should be maintained at 40 to 70%. Supplemental heat may be needed when dealing with infants or with sick or older animals. Note that some acclimation may be necessary before moving animals from a warm barn to the outdoors during winter months. Indoor facilities should be maintained with a negative air pressure, and ventilation should be provided to accomodate at least four air exchanges per hour (USDA recommendations for a cold-weather heated barn). Institutions are encouraged to check with their local authorities for air-exchange requirements when the public or personnel occupy the facility. Shower sprays or water baths should be offered in areas of relatively low humidity. Within any indoor facility, areas must be provided for food and water.

Fresh water should be available at all times and should be changed daily or be supplied from an automatic-fill or continuous-flow device. Regular cleaning and disinfecting should occur at a rate that inhibits the growth of algae and bacteria. Water devices should be constructed

2 Rhinos of all species need access to mud wallows (1) and/or pools (2) for skin health, temperature regulation and behavioral enrichment. The size of mud wallows should be guaged by the number of animals in the exhibit. Recommended sizes for rhino pools are listed in Table 17. (*Photo: San Diego Zoological Society*)

Visual barriers such as this "run-around" may help decrease aggression among rhinos by permitting animals to separate themselves from others if necessary. Barriers should be large enough to provide "safe zones" for the animals but not hinder public viewing. (*Photo: Oklahoma City Zoological Park*)

to prevent upset, spillage or leakage.

For black and greater one-horned rhinos, isolated stalls are essential; for white, they should be available when needed but may not be necessary. The indoor enclosure should include a minimum of 30 sq m (320 sq ft) per animal for white and greater one-horned rhinos and 18 sq m (200 sq ft) per animal for black rhinos (AZA Mammal standards) (Table 16). An additional 50% of adult space should be provided when a calf is present. This may be achieved by using more than one stall. Following weaning, a calf should be treated as an adult individual with respect to space requirements.

If the institution has only indoor facilities in which to maintain and/or exhibit rhinos, the minimum requirement is 186 sq m (2,000 sq ft) per rhino [15.2 x 12.2 m (50 x 40 ft)] plus the recommended indoor holding [30 sq m (320 sq ft) per individual for white and greater one-horned rhinos and 18 sq m (200 sq ft) per individual for black rhinos].

Separation Capabilities

The indoor facility should have the capacity to separate individuals for a variety of purposes. For white rhinos, although females may be housed together in a community barn following the guidelines of 30 sq m (320 sq ft) per animal, males should always be stalled individually. As indicated above, black and greater one-horned rhinos should be kept in individual stalls. The facility should also have an extra space or large stall to isolate mothers and calves or quarantine sick animals.

Currently, no quantitative data are available on the visual, olfactory or auditory capabilities of rhinos in relation to breeding success. Based on species ecology and behavior, however, it is believed that rhinos rely heavily on both olfactory and auditory senses for social communication. It is therefore recommended that indoor facilities allow these types of communication at certain times among individuals. Options include partial walls or pipe fencing to allow for physical separation without visual, auditory or olfactory separation.

Substrate and Bedding

A brushed or broom-finished concrete floor that is well-drained and insures adequate footing is recommended. Dirt flooring as the main substrate is not recommended. In addition, floor heat is recommended in colder climates. Bedding materials such as hay, wood shavings and hoofed-stock rubber matting are recommended for greater one-horned rhinos and optional for black and white rhinos. Other situations in which bedding is required include barns with rough substrates (which may cause skin ulcerations) or for additional warmth for sick animals or young calves. When introducing rhinos to new substrates, careful observations should be made to avoid the animals' excessive ingestion of the novel substrate, which could potentially lead to health problems such as impaction. The use of a power washing machine is recommended to disinfect barn areas. Additionally, rubber matting and bedding materials should be disinfected or changed regularly to prevent contamination.

Lighting and Special Features

Normal light cycles seem to be adequate for rhinos. However, if an animal is to be held

indoors for more than 12 hr (e.g., winter in cold-climate institutions), facilities should provide artificial or natural light sources to simulate natural cycles. Fluorescent lighting is an efficient light source that provides broad-spectrum illumination; however, skylights should be included whenever possible. Additionally, because greater one-horned rhinos are introduced for breeding purposes for a limited amount of time and closely observed, lighting is also necessary in outdoor enclosures for the observation of breeding at night.

Any new exhibit should include the capability for video systems. In addition, a scale for weighing animals is desirable and strongly recommended, though not required. Vehicle access to an indoor facility is also recommended. A restraint device or an area for restraint should be included in the design of every facility.

PHYSICAL RESTRAINT DESIGNS

Numerous institutions have constructed permanent physical devices to restrain their rhinos when necessary. Such "chutes" can be very valuable for physical exams as well as nutritional, reproductive or veterinary research projects. In addition to the following general information, please consult the Health chapter of this publication as well as Schaffer (1993) and Eyres, et al. (1995). Also, U.S. institutions that currently have chutes and may be able to provide additonal information include Henry Vilas, St. Louis, Sedgwick County, Oklahoma City, Henry Doorly, Cincinnati, Caldwell and Milwaukee County zoos and Fossil Rim Wildlife Center. Companies that may assist in chute design and construction include Animar Systems, Inc. (Springfield, MO; 417-889-4245) and Cummings and Son, Inc. (Garden City, KS; 316-277-2293). In general, it is highly recommended that institutions modifying rhino exhibits or constructing new ones incorporate a physical restraint area or device into their design considerations.

Several physical restraint designs are effective for rhinos. These range from a small restricted area in which to contain the animal to an area that contains one or more hydraulics that will "squeeze" together to restrict an animal's movement. In general, major restraint chute design considerations include strength, durability, type and function. It should be noted, however, that available space and animal size and disposition vary across institutions and should be individually addressed.

In general, both captive managers and researchers emphasize that the general restraint area should be an active component of daily rhino management. Methods to accomplish this vary. A restraint chute or restraint area can be designed so that the rhinos must pass through it to exit the barn into their yard. If rhinos are fed indoors, part of the feed (e.g., produce, grain) can be offered in the chute area. Finally, more extensive conditioning (See Rhino Training in the Management and Behavior chapter.) can be particulary effective in habituating rhinos to physical restraint. Such a program should be attempted prior to detaining a rhino in a chute for an exam.

Rhino chutes should be manufactured out of steel or a combination of steel and steel-rein-

forced wood. Some institutions have also used steel-strength aluminum (6061-T52 aluminum). Aluminum of this type is lighter and more maneuverable than steel, as well as potentially less stressful to rhinos because of "deader" sound properties than steel (i.e., when metal scrapes metal).

Permanent pass-through indoor restraint chutes (similar to those constructed for elephants) are especially effective for rhinos. With training, this type of chute may allow for daily rhino observations. Furthermore, inclement weather will not affect the use of an indoor restraint chute. The chute should allow restraint of the animal when it is passing through in either direction so that the shifting routine of the animal is not interrupted (Schaffer, 1993). The width of the chute should limit side-to-side movement while still allowing the animal to comfortably lie down. However, animals can become wedged in tight-fitting chutes if the sides cannot be released. To alleviate excessive forward movement of the animal when it lowers its head, two vertical bars that push in from the sides of the chute to the shoulders of the rhino may be utilized. Quick release of these shoulder bars often relieves agitated animals without having to release them completely.

High-walled chutes or bars over the top keep the animal from climbing or rearing up. Horizontal bars in the chute's entry gates and sides are hazardous for examiners when the animal lies down. Vertical bars on the sides can trap researchers' arms if the animal can move forward. If the animal's forward and side-to-side mobility can be limited, vertical bars or walls on all sides are recommended. The distance between these bars along the sides of the chute should be great enough to prevent the animal's foot from becoming wedged if the animal rolls on its side in the chute. For researcher safety, this distance can be divided with removable vertical bars.

Rhinos may slam swinging doors; thus, sliding or guillotine gates are safer. A rectangular opening in these gates for performing a palpation should not pin the arm of an examiner when the animal is shifting. The distance between the vertical sides of this rectangular opening must be wide enough for researcher safety while still limiting the space through which a rhino could squeeze. Also, the horizontal bottom bar of this rectangle should be only a few inches from the ground, as animals frequently lie down. Solid doors on the outside of these gates can be used to stop rhinos, as they may attempt to charge even small openings. Additionally, good lighting and accessible electrical sources are useful.

A closed chute (Figure 5) is another option that has been used successfully for the treatment of a rhino with a urinary-tract infection and another with infected lesions on its foot (Eyers et al., 1995). As noted in Figure 5, a typical closed chute has both front and back gates. The back gate restricts the rhino's movement by sliding forward. Additionally, the hind end of the rhino is supported by a v-design that prevents it from lying down. This design also allows additional safety for the staff while working with the animal. In many respects, a closed chute does not depend as strongly on conditioning of the rhinos as does a squeeze chute, though acclimation is recommended prior to attempting any treatments within the chute. The design of a closed chute might necessitate an outdoor location in most cases; therefore, the use of this type of chute may be limited by weather.

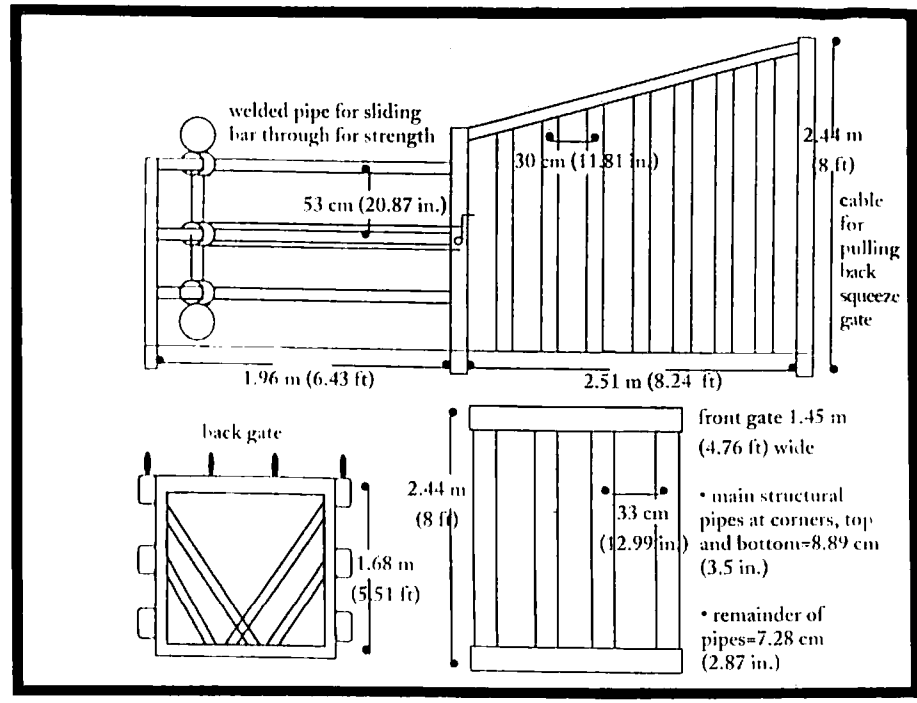


Figure 5. Closed stall rhino restraint chute. Note that a typical closed chute has gates that restrict the rhino's movement and prevent it from lying down. The advantage of a closed chute is that it does not depend as strongly on conditioning as does a squeeze or free stall chute. (*Eyers et al., 1995*)

A free-stall chute can be used for animals more sensitive to a confined enclosure (Figure 6). The design of this type of chute allows the rhino to enter or exit at its will and thus may help to keep rhinos calmer during procedures. Because there is free access, however, rhinos must be conditioned to target or stand still; thus, relatively non-invasive procedures also work best. Procedures that have been accomplished with a conditioned rhino in a free stall include ultrasound and serial collection of blood and feces (Eyres et al., 1995).

A free-stall design can easily be incorporated into an existing pen or stall, indoor or out. As stated, the open back of this type of chute allows the animal to enter and leave the structure at will. Protection of staff when working with the rhino is important, however, and a partial back wall constructed of vertical pipes allows staff to step out of the way (Figure 6).

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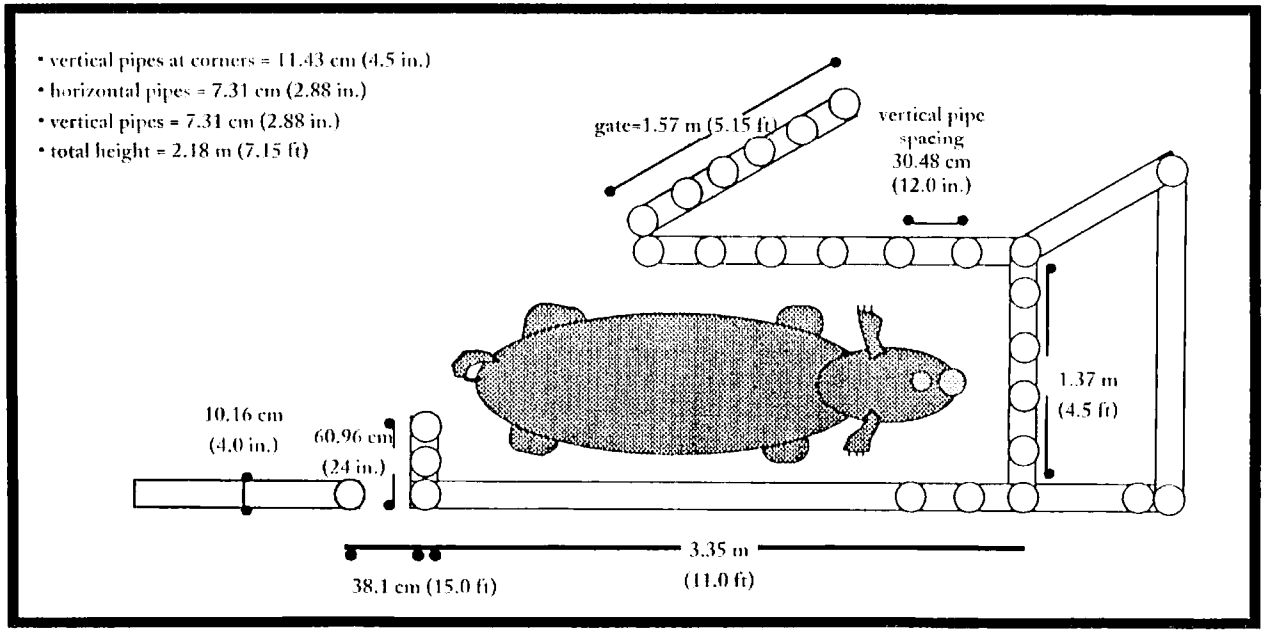

Figure 6. Free-stall rhino restraint chute. The design of a free-stall chute allows the rhino to enter or exit at will and can be used for animals more sensitive to a confined enclosure. This type of restraint chute, however, is best used for relatively non-invasive procedures and with rhinos that have been conditioned to target or stand still. (*Eyres et al., 1995*)