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Hydrogeologic Relationships to Structural Failure Chadron State College, Nebraska

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OTHER WATER-RELATED SUBJECTS

HYDROGEOLOGIC RELATIONSHIPS TO STRUCTURAL FAILURE

CHADRON STATE COLLEGE, NEBRASKA

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Inordinate structural failure in several buildings on the Chadron State College campus has occurred in recent years. Disregard for hydrogeologic conditions and their effect on foundation material accounts for part of the damage.

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THE PROBLEM

Chadron State College experienced a period of campus growth during the 1960's. Several major buildings were added in those years and in the early 1970's. During the period 1964-71, structural conditions indicative of movement or settlement were noted in several of the new buildings. In particular, the National Guard Armory, the Armstrong Physical Education Building (gym), and the Kline Campus Center (Student Union) were showing stress and failure. The year in which major damage occurred–or at least it had proceeded to the point that repairs were required in these facilities–was 1970.

On December 14, 1970, Kirkham & Michael Architects and Engineers made observations of the structural conditions, summarized as:

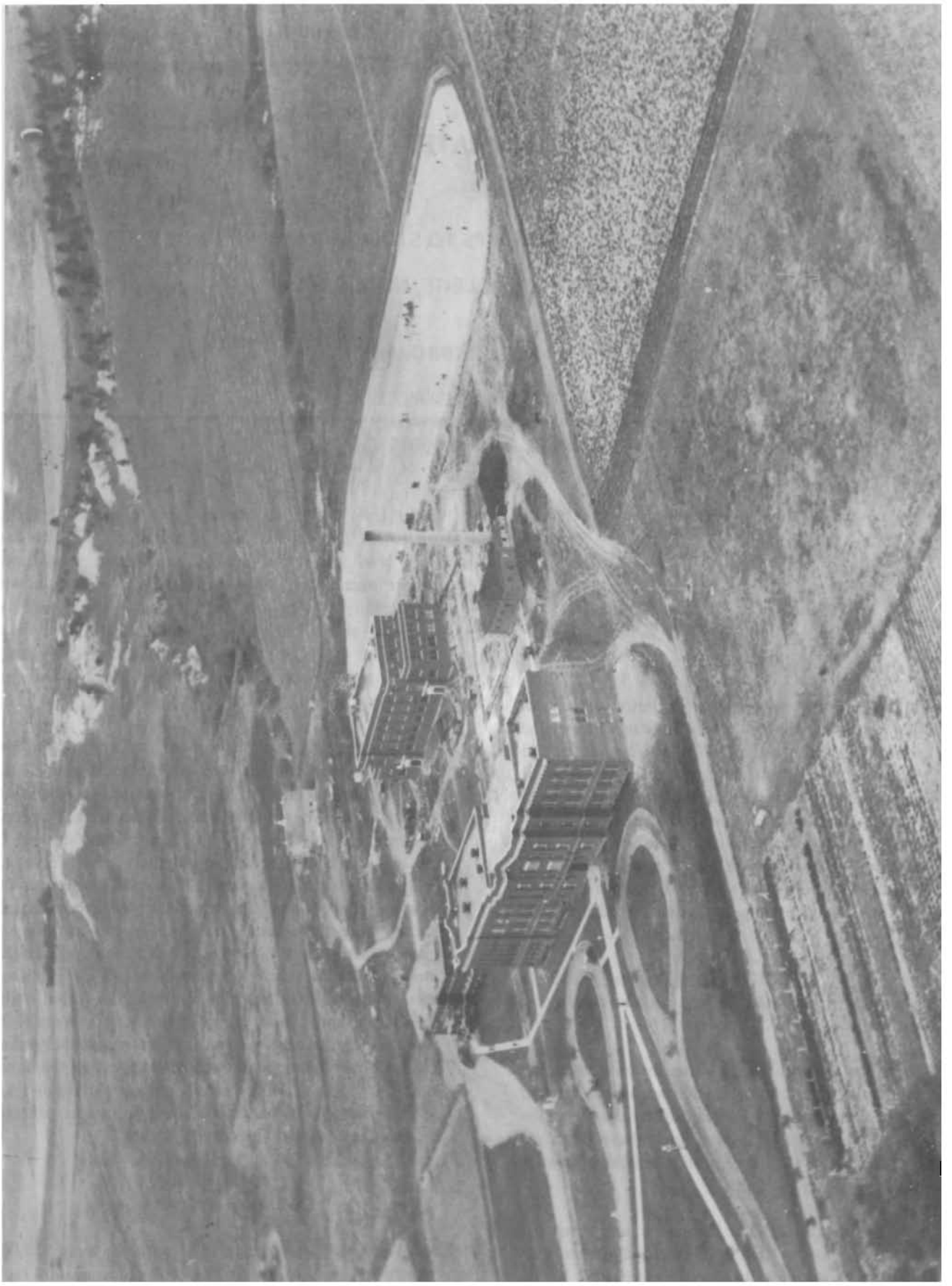
National Guard Armory . . . "extensive settlement has occurred to the extent that exterior walls have cracked clear through and evidently a settlement or tipping action of those walls is occurring. Some bricks have fallen off the exterior faces and some separations in the cracks are up to as much as 2 to 3 inches."

Kline Campus Center . . . "extensive settlement has occurred to the extent that wall cracks similar to that observed on the Armory Building has occurred. It was noted that in the mechanical equipment room or the lower level in the southwest corner of this building settlement has cracked the foundation wall. The first floor level has settled to the extent that plaster wall closure surrounding the mechanical room has bowed considerably . . . hollow metal frames for glass walls on the west side of the lower level cafeteria have been crushed to the extent that a normal 2-inch frame is only about 1 to 1½ inches thick. It was surprising that the glass had not shattered."

Armstrong Physical Education Building . . . "the second column from the west on the south side of the high bay area of the gym has some distress located at the balcony level. The column has a diagonal crack starting at one corner at floor level and proceeding upward to the opposite corner, then around the corner proceeding back down to the floor level. This small portion of the face of the column has separated by approximately ½ inch from the column itself and appears as though it may be caused by a tipping action of the column. On this same column line only at the north side of the gym area, there is observed similar action only at floor level rather than at balcony level. Some overhead framework for gymnastic equipment above the balcony level has pulled loose from the long concrete beam supporting the barrel vault arch roof. A flanged connection supporting one side of this framework has pulled loose from this concrete beam approximately 2 inches to 3 inches."

REMEDIAL ACTION

National Guard Armory: In 1972, approximately $25,000 in repairs were made to the drainage and air circulation (subfloor) system in the north portion of the Armory. During



1975-76, $60,000 was expended for the rebuilding of the north wall of the Armory building.

Kline Campus Center: In 1971, $15,000 was expended for underpinning the southwest corner of the building by driving a 36-inch-diameter caisson 80 feet deep and filling it with reinforced concrete. An additional $19,000 was expended in 1972 for cosmetic repair and restoration. In 1973, $12,000 was needed to restore air conditioner damage caused by building settlement.

Armstrong Physical Education Building: In 1974, $136,500 was spent for steel bands tying the east and west walls together, the replacement of the roof (which had been damaged by shifting), relevelling and relaying the gym floor, and cosmetic repair.

In spite of the remedial repair, failure continued with 1975 reports by the building manager indicating . . . "joints buckling, plaster cracking, and floor lowering" in the northern part of the southern half of the Kline Campus Center. In the same year, the Armstrong Physical Education Building was experiencing continued roof leakage and floor shrinkage.

CAUSE OF THE PROBLEMS

Evidence that hydrogeologic factors played a role in the structural failure was indicated during the excavation and installation of the 36-inch-diameter caisson under the southwest quadrant of the Campus Center in 1971. As the caisson was sunk, water had to be removed at an estimated rate of 200 gallons per minute, in order to proceed with the excavation. The large yield of water prompted this preliminary analysis of the campus geomorphology and geohydrology.

An air photo (Fig. 1) taken in 1920 by Dr. G. E. Condra, State Geologist, shows the confluence of two washes at or near the location of the Armstrong Physical Education Building. A vertical air photo (Fig. 2), taken about 1965, shows that these washes had been filled by simple (noncompacted) procedures and that the football stadium and practice field, the college library, and the north half of the Campus Center were under construction. The Physical Education Building and the National Guard Armory had been completed before 1965.

Projection of the wash alignments into the fill areas indicates the location of the gym is on the west wash alignment at or close to the juncture with the east wash. Similar analysis suggests the Armory is on the east wash alignment. The southwest part of the Campus Center extends onto the fill of the wash alignment, down gradient from the juncture of the east and west wash.

The high yield of ground water from the caisson excavation indicated ground water movement through the more permeable fill of the old wash alignments. Although surficial evidence of the washes was obliterated, their position could be reconstructed from the air photos. This was projected further, by plotting the position of shallow, domestic wells in the city, and connecting their alignment with the unmodified remnants of the washes, on the hill south of the campus. Topographic expression, although modified by housing development, helped to locate the former drainage pattern.

A plot of the domestic wells in the city is shown in Figure 3. Most of the well locations are coincident with the approximate alignments of the pre-construction (urban) drainage features. The data from Condra's photo allow connection of the unmodified portions of the washes, south of the campus, with the well concentrations and topographic lows, defining the original drainage pattern, and is coincident with the damaged structures.

It should also be noted that successful wells are in topographic lows along the postulated pre-construction drainage pattern. The low porosity and permeability of the sandy silts of the Chadron Formation and the Tertiary White River Group of sediment are not generally conducive to successful wells. The alluvium along the drainage pattern established by the pre-construction washes would be of much better hydrologic character, allowing flow of ground water and successful well drilling.

In order to present a well-kept and well-landscaped appearance, campus playing fields and lawns are irrigated by sprinklers from approximately mid-April until mid-September. Water that is not evaporated or transpired readily infiltrates the permeable fill in former washes, and migrates beneath the damaged buildings. The irrigation water joins water that is derived from natural runoff that still seeks the former drainage courses where it is not blocked by dams or diverted by streets and storm sewers.

If the proposed Activity Center (field house) is attached to the Armstrong Building, it is likely to be subject to similar structural failure.

SOLUTION

The available evidence indicates that the unconsolidated fill material in the former washes contains, stores, and transmits a considerable volume of water. Since buildings erected on the old fill exhibit structural failure, I would like to suggest the following:

1. Dewater the fill material in the vicinity of the damaged building by pumping from a series of shallow, low-cost wells. The water removed could be used to irrigate campus lawns and thereby save potable water for human consumption. Dewatering would reduce the instability of the foundation material for the damaged

buildings and should be done before repair of those buildings is undertaken.

2. Make extensive studies of foundation materials and have design awareness to prevent future buildings from being built on, or near, the former wash alignments.

3. If the proposed field house is to be attached to t Armstrong Building, the only feasible location south of the current structure. No portion of t structure should extend over the previous wash alig ment.

Figure 2. Vertical air photo (ca. 1965) of the Chadron State College Campus. Washes have been obliterated. The Armstrong Physical Education Building, the south half of the Kline Campus Center, and the National Guard Armory had been completed. The library and north half of the Kline Campus Center were under construction. (Photo courtesy of Linda Rector.)

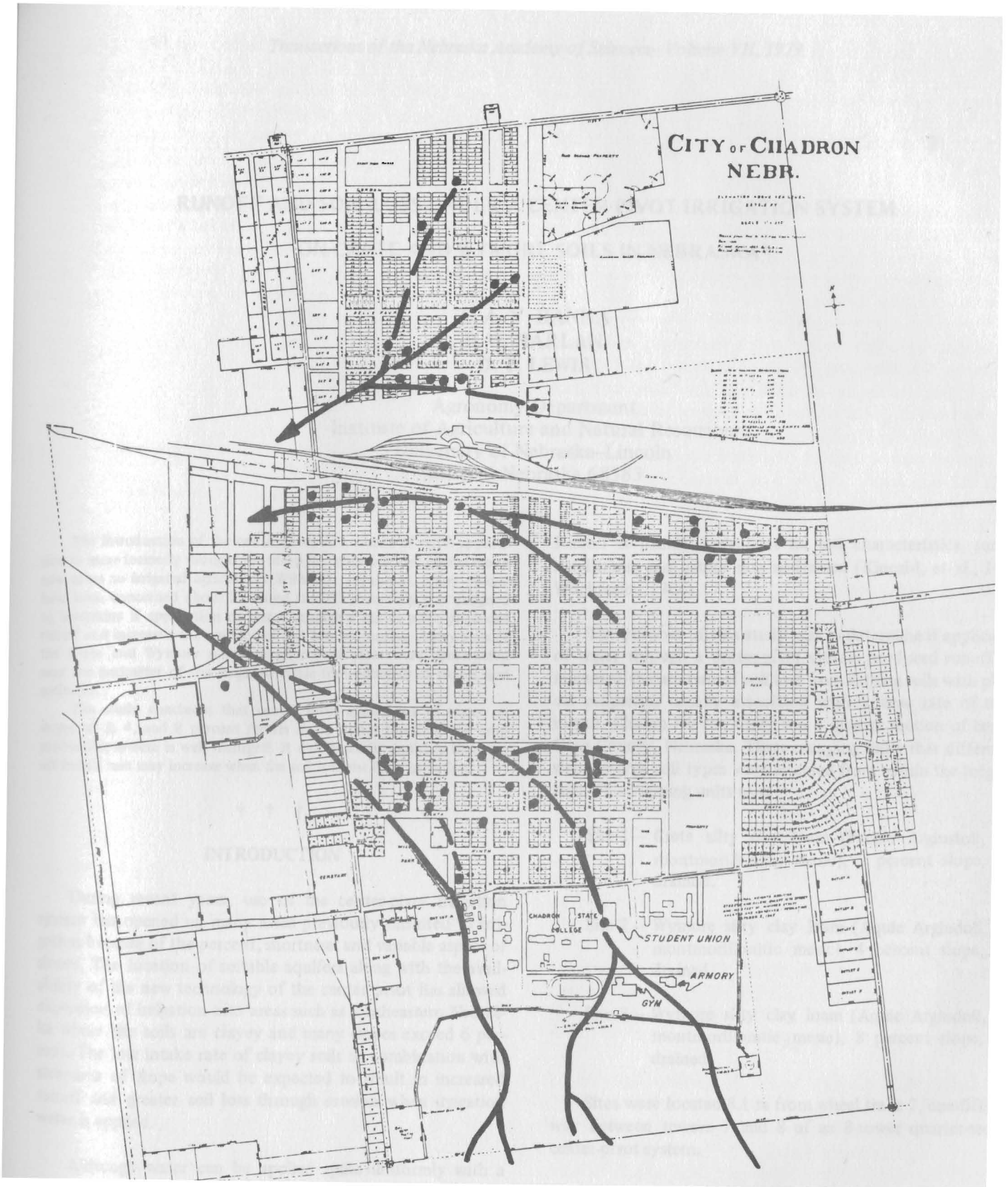


Figure 3. A map of the city of Chadron showing the location of known shallow wells. Projected topographic alignments of former drainage patterns are coincident with the well locations. Dashed lines indicate a lesser degree of certainty of position. (Photo courtesy of Linda Rector.)